AUCTIONS FOR UNIVERSAL SERVICE SUBSIDIES

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Abstract

This dissertation provides a comparative theoretical analysis of auctions and traditional schemes for the allocation of subsidies. In particular, it considers the "Universal Service" subsidies mandated by the Telecommunications Act of 1996 for telephone service in high-cost areas.

A first basic model focuses on the level of subsidies required when the cost of serving different consumers varies even at small scales of aggregation. Under a so-called "EPOS scheme," firms receive a fixed uniform subsidy for each consumer they serve. In order to achieve the Universal Service goal, this subsidy must make even the most costly consumers profitable at the regulated price. A "COLR auction," instead, achieves the Universal Service goal by appointing a "Carrier Of Last Resort," i.e., a firm with the obligation to offer service at the regulated price to all consumers in the given area. If subcontracting is not too inefficient, the equilibrium level of subsidies in this model would then be (at most) the average of the second-lowest net cost for each consumer. In a wide range of circumstances, this is less than what required by EPOS schemes.

The model is extended to sequences of auctions with durable production goods. Unlike the few other formal analyses of this problem, the possible transfer of assets is left to free bargaining among firms. Other extensions cover the use of reserve prices, the appointment of multiple COLRs, incumbents' obligation to lease their assets to entrants, economies of scale and firms' asymmetric private information.

The focus then shifts from the level of subsidies to the incentives for service quality. This is a tougher goal for COLR auctions. Competition "for the market" at the

auction stage reduces the scope for later competition "in the market." Moreover, competition "in the market" requires the use of per-consumer (not lump-sum) subsidies and these make auctions more vulnerable to collusion.

The major policy conclusion is that auctions can often be a valid alternative to more traditional subsidy schemes, but they do not eliminate the need for close regulatory oversight, especially with respect to service quality.

Preface

Since the beginning of the long process of liberalization of the U.S. telecommunications industry (and of other network industries worldwide), the social goal of "Universal Service" (vaguely defined as providing affordable service to all citizens) has often been put forward to defend the traditional structure of regulated monopolies from the encroachment of competition. This goal, so the argument went, requires distortions in the structure of prices that would be incompatible with competition. For example, low-cost consumers should be charged more than the cost of serving them in order to subsidize the provision of service to high-cost consumers. Competitors, if allowed, would "cream-skim" the most profitable segments of a market and subtract revenues from the monopolist who then would have to raise the prices charged to the more vulnerable consumers. Assuming, for the sake of argument, that subsidies are needed to achieve universal service, the logic of the argument is correct. Its premises, however, are not. Competition can in fact live and thrive even with highly "distorted" price structures – and luckily so, as practically all markets are subjected to different kinds of taxes, subsidies and other "distortions."

The Telecommunications Act of 1996, for all the faults it may have, has at least the merit of recognizing that competition and subsidization can go together. Indeed, the Act actually advocates both: it has wiped out all legal obstacles to entry in the markets for local telephone service and it calls for *explicit* subsidies to support something like a nation-wide uniform pricing policy for basic telephone service.

This dissertation does not comment on the wisdom of this policy, but deals instead with the problem of how it could best be implemented. It does so at a fairly abstract theoretical level by studying some of the properties of auctions as means to procure/subsidize the provision of universal service in high-cost areas. The *effectiveness* of auctions in this respect is quite easy to establish, but of course the real issue is their *efficiency* relative to alternative means. As a first benchmark, this dissertation provides a comparative analysis of auctions with respect to a traditional scheme of fixed uniform subsidies.

My first approach to this study was, I believe, typical of theoretically trained doctoral students: I tried to fit the problem into the literature and ask the usual questions. Thus I started looking at issues of asymmetric information and ranking of alternative auction formats.[1] However, already my first experience of the regulatory debate on the topic (a workshop organized by the California Public Utility Commission in May 1997) showed me that the "real world" was mainly interested in quite different questions. This realization was further reinforced by my later consulting work at Charles River Associates on the auction proposal presented by GTE Corporation.

The analysis of this dissertation thus focuses largely on two issues that acquired greater prominence in the regulatory debate. First, the expected level of subsidies required by the two mechanisms when the cost of serving different consumers varies in a manner that is not observable by regulators. Cost heterogeneity at the national level is precisely what creates the sort of universal service problem investigated here. It turns out that the issue persists even at scales as small as Census Block Groups and that auctions deal with it much better than fixed subsidies.[2] Second, the ability of the two mechanisms to provide sufficient incentives for service quality that is not easily observed by regulators. On this front, auctions tend to fare less well.[3] These results suggest that, even with free entry and explicit subsidies, a universal service policy still needs to employ regulators to monitor product quality and/or firms' costs.

More than five years have passed since the enactment of the Telecommunications Act of 1996 and still there has not been a final decision by the Federal Communications Commission (nor, to my knowledge, by state regulatory commissions) on how to

[1]A trace of that first approach remains as Section 3.4 of this dissertation.

[2]See Chapters 2 and 3.

[3]See Chapter 4.

allocate universal service subsidies to carriers in high-cost areas.[4] I cannot really blame them. The stakes are high and the issues complex – surely more complex than I thought when I began this research. I hope that the analysis reported here will help clarify some of those issues, but I know that much more work remains to be done. Thus I end this Preface, and get back to work.

[4]See Chapter 1.

Acknowledgements

My first thanks go to my principal advisor Paul Milgrom for suggesting the topic of this dissertation – and for his patience in following its all too slow development. I once read that dissertation advisors should not be thanked for dissertation advice because that's their job after all. I disagree. Paul Milgrom, Bob Wilson and David Salant have been very helpful and deserve my thanks, which I gladly offer.

I also received useful comments on several parts of this dissertation from Douglas Bernheim, Robert McMillan, Matthew Shum, Padmanabhan Srinagesh, Steven Tadelis, Dennis Weller, seminar participants at Stanford University and the Congressional Budget Office, and an anonymous referee of the *Journal of Regulatory Economics*.[5]

Parts of this dissertation have been written at the Palo Alto office of Charles River Associates, Inc. I would like to thank CRA and in particular Bridger Mitchell and Padmanabhan Srinagesh for creating a very pleasant work environment.

Financial support for this research has been provided by a grant from GTE Corporation (now Verizon, Inc.) for the 1997-98 academic year and by the Olin Dissertation Fellowship from the Center for Economic Policy Research (now Stanford Institute for Economic Policy Research) for the 1998-99 academic year. A "Marco Fanno" scholarship from Mediocredito Centrale (Italy) allowed me to study at Columbia University in the 1992-93 academic year. The scholarship was renewed and allowed me to spend the following year at Stanford University, eventually leading to this dissertation. I gladly thank these institutions for their support.

[5]Earlier versions of parts of this dissertation have been published in the *Journal of Regulatory Economics* (Sorana, 2000).

Finally, I offer my special thanks to Giovanni Facchini for his friendship and for taking care of all the administrative burdens involved in the actual filing of this dissertation.

A doctoral dissertation is generally the culmination of one's formal educational process (the informal one never ends). I believe it is the right place to thank those who helped throughout the whole process, beyond the dissertation itself. Here I only have the space to mention a few of them. Without Luigi Frey's prodding, I may still be working at my senior thesis at the University of Rome I on neo-keynesian equilibrium theories of equilibrium. Ugo Pagano, at the University of Siena, fueled my interest in the theory of the firm and started the chain of events that, with the help of Graciela Chichilnisky and Geoffrey Heal, brought me to Columbia University and then to Stanford. At Columbia University, Paolo Siconolfi's course on classical general equilibrium theory and John Donaldson's course on macroeconomics were models of pedagogy. Being a graduate student at Stanford was a kid-in-the-candy-store experience. I particularly enjoyed the courses on Political Economy by David Baron, Dynamic Economics by Mordecai Kurz, Economics of Organizations by John Roberts, Industrial Organization by Tim Bresnahan, Market Design by Bob Wilson and Intensional Logic by Johan van Benthem. The informal workshop organized by Tom Sargent was one of the best things that a Ph.D. program in Economics can offer. If I have learnt anything of the craft of economic modeling, I have learn it from Tom Sargent and, especially, from Paul Milgrom.

Fellow students can be a source of learning second to none. A full list is impossible, but Claudio Ricci and Andrea Prat were particularly helpful and deserve a special mention. After a brief spell in kindergarten, I and Stefano Guerrini have never been classmates and his fields of research (in theoretical computer science) could hardly be farther away from mine. But we grew up together, creating our views of the world by explaining them to each other, so he has probably had a larger influence on my scientific development than anyone else I mentioned so far.

There is no doubt, however, on who has had the strongest influence on my education: Beatrice Rinaldi and Marino Sorana, my parents. They taught me its value and, more importantly, they instilled in me a passion for learning – perhaps too much passion, they may have thought when I left Italy to follow my studies. They have always supported me (not only spiritually) and I will never find the way to thank them enough.

This brings me to another impossibly long list: the one of those who helped my studies by inducing me to have fun in ways other than studying – and thus keep my sanity. I will only mention the two most important elements of that list: my daughter Sophia and my wife Sun Yun. They have shown the perfect combination of understanding, patience and stimulation. And they made me happy to go back home every evening, even though so much work remained to be done. They will be glad to know that at least *that* work is done.

Since I left Italy, my uncle Donato kept reminding me that I had promised to give him a copy of my dissertation. His lung cancer grew too fast for me to keep my promise. I dedicate this dissertation

alla memoria di
Donato Rinaldi.

Contents

Chapter 1

Introduction

1.1 Introduction

Section 254 ("Universal Service") of the Telecommunications Act of 1996 requires, roughly speaking, that "core" telephone services be available at the same "affordable" rates throughout the United States and that explicit subsidies be used to compensate carriers in high-cost areas.[1] But how are these subsidies to be determined and how should they be distributed among carriers exactly?

Soon after the passage of the Act, the Federal Communications Commission (FCC) began to consider "distributing high-cost assistance on the basis of competitive bids."[2] In its May 1997 *Report and Order on Universal Service*, the FCC decided to focus on a different subsidy scheme,[3] but it also confirmed its interest in the use of auctions for Universal Service subsidies and the need for further study into the matter.[4]

[1]See section 1.2 for a more extensive description of the parts of the Telecommunications Act of 1996 (hereinafter referred to as the "Telecommunications Act" or simply "the Act") related to this dissertation.

[2]Paragraph 35, *Notice of Proposed Rule Making and Order Establishing Joint Board*, CC Docket No. 96-45, March 8, 1996. State regulators have also been studying the possibility of auctions for universal service subsidies. Indeed, the Hawaii Public Utility Commission has already run one such auction in 1996, although the outcome is still being contested in court. See Appendix D of FCC (1999) for a brief description.

[3]See section 1.2.1 for a description and a critique.

[4]More recently, the FCC has advocated the use of auctions for the allocation of Universal Service subsidies to unserved areas (FCC, 1999).

The goal of this dissertation is to help satisfy that need by providing a formal comparative analysis of two classes of competitive mechanisms for the allocation of subsidies, one based on auctions and one that fixes the level of subsidies administratively.[5]

First, in order to see *how* an auction mechanism could be used to allocate Universal Service subsidies, one should look at the Universal Service problem as a procurement problem. Essentially, the regulator wants to procure the services of one or more firms which would provide telephone services of given (minimum) quality at a given (maximum) price to a given sets of consumers (e.g., all consumers living in a given area). Once thus defined, it is clear that the Universal Service problem could be "solved" by using a kind of procurement auction that goes under the name of "Carrier Of Last Resort" (COLR) auction.[6] In a COLR auction, firms typically submit "bids" ("asks" would be a more appropriate, but less conventional term) indicating the (lowest) subsidy at which they are willing to become a "Carrier Of Last Resort," that is, to acquire the (COLR) obligation to offer the supported services at the regulated price to all consumers in a given area. Both the amount of the subsidy and the identity of its recipient(s) would thus be determined by the firms' bids according to the specific rules of the auction.[7]

COLR auctions are, admittedly, a rather peculiar sort of procurement auctions. The regulator/procurer is not really interested in the presence of COLRs *per se*, but in their effects on social welfare. This will ultimately depend on market outcomes that the regulator cannot fully control. For example, the regulator may be unable to (costlessly) observe the quality of service provided by the COLRs because consumers, not regulators, are the ultimate receivers of that service.[8] Similarly, the legal impossibility of granting monopoly franchises marks another difference with standard

[5]Most of the analysis in this dissertation, can also be applied to other subsidization programs, but I will focus on the Universal Service context.

[6]COLR is usually pronounced like "color."

[7]Clearly, the rules of the auction would also have to specify the form of the subsidy, i.e., whether it is paid as a lump-sum, on a per-customer basis, or as a (more complex) function of a COLR's customers (see Chapter 4).

[8]In a one-period model this would be equivalent to unverifiability of quality in standard procurement problems. In a dynamic context, however, it leads to more severe problems that are discussed in Chapter 4.

procurement auctions. COLRs will get their revenues not only from regulators (the Universal Service subsidy), but also from consumers and this fact significantly alters the firms' strategic possibilities.[9]

Traditionally, the COLR obligation was (and in most cases still is) assumed by a regulated monopolist.[10] The mechanism that will be compared with COLR auctions in this dissertation is, in a sense, the polar opposite of this tradition. It is, in fact, a completely decentralized way of satisfying the Universal Service goal: like the FCC scheme to be discussed in the next section, it gives a fixed unit subsidy to any firm that actually provides the Universal Service package and (unlike the FCC scheme) it abstains from any other form of regulatory intervention.[11] Since this mechanism allows any firm to enter or exit the market (and get or give up the subsidy) also after the subsidy level is determined, I will refer to it as an *ex-post open subsidy* (EPOS) scheme. By contrast, COLR auctions are open *ex-ante* (i.e., before the auction) because any firm can participate on an equal basis, but they are closed *ex-post* because the auction determines not only the level of subsidy, but also the (limited) set of firms that will be allowed to collect it - at least until the next auction.

The regulators' role in an EPOS scheme is limited to the choice of the appropriate level of subsidies; this should be kept low in order to reduce the distortion, but high enough to satisfy the Universal Service goal. It is this choice that COLR auctions delegate to the market and, more precisely, to the firms' bids.[12]

The main contributions of this dissertation are as follows. First, it identifies a wide range of circumstances in which COLR auctions can reduce the cost of the Universal Service policy compared to EPOS schemes. The analysis focuses on the *heterogeneity* in the cost of serving different consumers and the possibility of *subcontracting* after the auction. In Chapter 2 it is shown that, in a stylized model with fixed service

[9]This is especially important when subsidies are paid on a per-subscriber basis (see Chapter 4).

[10]In the procurement context, this can be seen as the analogue of procurement via long-term relational contracts (see Goldberg, 1976).

[11]This is a minor variant of the traditional subsidies-as-negative-taxes schemes of public economics textbooks; the only difference is that the subsidy is paid only if the transaction price is sufficiently low. Without this restriction, the minimal fixed subsidy that achieves the Universal Service goal may be somewhat higher, but the analysis would be almost identical.

[12]Regulators can put a ceiling on the amount of subsidies also when using COLR auctions, namely by imposing reserve prices (i.e., maximum bids).

quality, a COLR auction without any reserve price will satisfy the Universal Service obligation at lower cost than the best fixed subsidy scheme if there is enough competition for each consumer (possibly by different sets of firms for different consumers) and/or if the winner of the auction can appropriate a sufficiently large share of the potential gains from trade in subcontracting. Furthermore, if a fixed subsidy equal to r achieves the Universal Service goal, then a COLR auction with reserve price r will also do so and at a lower cost when a fairly mild condition is satisfied.[13] Chapter 3 shows that the qualitative results obtained in Chapter 2 are quite robust to the consideration of economies of scope, durability of productive assets, imposition of unbundling obligations on incumbents and incomplete information among firms.

The second main contribution of this dissertation is to show (in Chapter 4) that attempts to design COLR auctions that provide good *incentives for quality of service* (i.e., using per-subscriber subsidies and appointing several COLRs per service area) are generally not very effective and may be particularly vulnerable to *collusion among bidders.* The problem is that the use of per-subscriber subsidies increases the range of possible punishments for those who defect from collusive agreements. The appointment of several COLRs per area makes things worse by reducing the cost of carrying out such punishments. In some cases, *competition in the market* after the auction and *competition for the market* in the auction are mutually incompatible, although some specific modifications in the auction rules may sometimes alleviate this problem.

It may be useful to state at this point what is *not* in this dissertation. First, there is no discussion of the rationale of the Universal Service policy itself. I believe that finding an interpretation of the Act's Universal Service policy in terms of maximization of a social welfare function would be an arduous task. Even if public intervention to increase access to the telephone network were warranted (e.g., because of some kind of network externalities), it would not follow that the cross-subsidy from urban to rural areas mandated by the Act would do the job - let alone do it better than other policies, e.g., targeted subsidies to low-income consumers. Similarly, even if rural

[13] This does not imply that COLR auctions with reserve prices are always superior to fixed subsidy schemes under that condition. For example, the performance of COLR auctions may be more sensitive than that of fixed subsidy schemes to mistakes in the choice of the maximum subsidy (see Chapter 2 for a more complete discussion of this point.

areas had higher welfare weights than urban areas, subsidization of telephone rates seems an inefficient way to transfer money there. Here I just note the widespread adoption of this kind of Universal Service policy and look for ways to implement it at the lowest cost.[14]

Second, this dissertation does not address the issue of whether deregulation is desirable. There seems to be an overwhelming consensus that promoting competition in the telecommunications industry is a worthwhile social goal. There is probably much less consensus on what deregulation really means in this context, as other forms of regulation (e.g., access pricing policies) may be required for efficiency in the competition across different networks.[15] Following the Telecommunications Act, the analysis in this dissertation assumes that entry into the industry is free and that the subsidization mechanism is "competitively neutral," i.e., it does not discriminate between incumbents and entrants, nor between firms employing different production technologies. However, the possibility of imposing some kinds of asymmetric obligations on incumbents is considered in Chapter 3.

Finally, this dissertation does not address the issues of detailed auction implementation. These are briefly summarized in the concluding chapter and left to further research.

The rest of this chapter provides an introduction to the Universal Service laws and regulations in the U.S. after the passage of the Telecommunications Act of 1996 and a survey of the literature related to this dissertation.

1.2 Universal Service after the Act

The Telecommunications Act of 1996 has fundamentally changed the Universal Service policy of the United States, giving the goal of Universal Service its strongest and most explicit endorsement ever:[16]

[14] Policies to eliminate, or at least reduce, the geographic disparities of telephone costs are also present in Europe, Australia and Asia.

[15] See Laffont and Tirole (2000) for an up-to-date survey.

[16] It must be noted that the term "Universal Service" was originally used in the sense of "universal network interoperability." The current meaning (access to telephone services for everybody) emerged

> " UNIVERSAL SERVICE PRINCIPLES. The Joint Board and the Commission shall base policies for the preservation and advancement of universal service on the following principles:
>
> 1. QUALITY AND RATES. Quality services should be available at just, reasonable, and affordable rates.
> 2. ACCESS TO ADVANCED SERVICES. Access to advanced telecommunications and information services should be provided in all regions of the Nation.
> 3. ACCESS IN RURAL AND HIGH COST AREAS. Consumers in all regions of the Nation, including low-income consumers and those in rural, insular, and high cost areas, should have access to telecommunications and information services, including interexchange services and advanced telecommunications and information services, that are reasonably comparable to those services provided in urban areas and that are available at rates that are reasonably comparable to rates charged for similar services in urban areas."[17]

At the same time, the Act has given the final blow to the traditional way of pursuing the Universal Service goal. The old web of implicit cross-subsidies and, in particular, the practice of mandated geographic price averaging by large regulated monopolies, have not been merely undermined by the lifting of legal entry barriers;[18] they have been clearly repudiated in favor of the (Universal Service) principle of explicit subsidies:

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only in the last three decades (see Mueller, 1997).

[17]Section 254(b). The Act has also introduced a new Universal Service goal that will not be considered in this paper: "Elementary and secondary schools and classrooms, health care providers, and libraries should have access to advanced telecommunications services."

[18]Section 253 (Removal of barriers to entry) states in its opening paragraph:

> "No State or local statute or regulation, or other State or local legal requirement, may prohibit or have the effect of prohibiting the ability of any entity to provide any interstate or intrastate telecommunications service."

Actually, Section 271 of the Act requires that Bell operating companies take a series of steps to open their own intraLATA (local service) markets to competition before they can enter the interLATA (long distance) market.

> "Specific and predictable support mechanisms. There should be specific, predictable and sufficient Federal and State mechanisms to preserve and advance universal service."[19]

The design of the Universal Service policy can be thus divided in three parts: the definition of the Universal Service obligation (i.e., the set of subsidized "core services" and the "affordable price" at which they must be available),[20] the design of the tax scheme used to finance the Universal Service Fund, and the design of the subsidy scheme that will allocate those funds to guarantee the satisfaction of the Universal Service obligation. These three components are related and, in principle, should be decided simultaneously.[21] The complexity of the issues involved, however, suggests that addressing them separately is a practical necessity.

The FCC has already defined the set of "core services" that will be supported at the federal level:

> "[W]e define the 'core' or 'designated' services that will receive universal service support as: single-party service; voice grade access to the public switched network; Dual Tone Multifrequency ("DMTF") signaling or its functional equivalent; access to emergency services including, in some circumstances, access to 911 and Enhanced 911 ("E911"); access to operator services; access to interexchange service; access to directory assistance; and toll-limitation services for qualifying low-income consumers." [22]

The details of the contribution scheme for the Universal Service Fund have not yet been settled, but (like the determination of "affordable" prices) they will be determined independently of the subsidization scheme. This dissertation thus focuses on the latter.

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[19]Section 254(b). Some forms of explicit subsidies were already in place before the passage of the Act (see FCC, 1996). Incidentally, the Act never mentions the word "subsidy" and uses expressions such as "support payments" or "high-cost assistance" instead. I will use all these terms interchangeably.

[20]Hereinafter also referred to as the "Universal Service package."

[21]For example, whether a kind of service ought to be subsidized should depend on the social cost of the corresponding subsidies, which in turn depends on the financing scheme.

[22]Paragraph 56 of the Report and Order on Universal Service; 47 Code of Federal Regulations, Section 54.101a.

The expenditures required to satisfy the Act's Universal Service objective are hard to quantify, but they are certainly considerable. A study by the Telecommunications Industries Analysis Project (see Weinhaus *et al.*, 1995) gives an estimate of five billion dollars per year for the subsidy from urban (generally low-cost) consumers to rural (generally high-cost) ones.[23] This estimate does not consider the further requirement that prices be "affordable." It is of course impossible to quantify the effects of this requirement until the regulatory authorities specify what "affordable" really means. If it means the conservation of the whole traditional pattern of cross-subsidization (including the subsidies from long-distance to local service), then the total amount of subsidies could reach twenty billion dollars per year.[24] The most recent "official" estimates of high-cost Universal Service support are on the order of 2.5 billion dollars for non-rural carriers[25] and one billion dollars for rural ones.[26]

The Act specifies that Universal Service subsidies will be paid out of a Universal Service Fund financed by mandating contributions from providers of interstate telecommunications services. Such a restricted tax base suggests that the social cost of Universal Service funds is likely to be very large.[27] It is therefore very important to choose a subsidization scheme which, while respecting the letter and spirit of the Act, also tries hard to minimize the total amount of subsidies. The normative suggestions

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[23]In the telecommunications industry, and more generally in network industries, costs are inversely related with the density of the subscribers' population. Since urban and suburban areas are more densely populated than rural areas, they tend to have lower costs. The equalizing Universal Service subsidies thus generally flow from urban to rural areas. For a short description of the technology of local exchange networks, as well as for an excellent introduction to the economic and regulatory debate in the U.S., see Vogelsang and Mitchell (1997). For a more technical, but still accessible, introduction to telecommunications technologies see, e.g., Freeman (1999).

[24]Weinhaus *et al.* (1995) mention several studies that focus on different aspects of the cross-subsidy structure (e.g., urban-to-rural, local-to-long distance, etc.) The $ 20b estimate is from Monson and Rohlfs (1993).

[25]*COMMON CARRIER BUREAU RELEASES ESTIMATED STATE-BY-STATE HIGH-COST UNIVERSAL SERVICE SUPPORT AMOUNTS FOR NON-RURAL CARRIERS FOR 2001*, DA 00-2746, CC Docket No. 96-45, December 8, 2000. Available at the FCC website http://www.fcc.gov/ccb/universal_service/highcost.html.

[26]*Rural Task Force files revised November 10, 2000 estimates of the financial impact of implementing its Recommendation*, available at the Rural Task Force website http://www.wutc.wa.gov/rtf/rtfpub.nsf?open.

[27]The mandatory contributions required by the Act are not considered "taxes" from a legal point of view. But, by any other name, a tax would still distort the same.

in this dissertation are mainly based on this goal.

1.2.1 The FCC's *Universal Service Order*

As mentioned above, the FCC has shown considerable interest in the use of auctions to allocate Universal Service subsidies, based on the belief that "competitive local exchange markets may develop even in high-cost areas."[28] The FCC, however, felt that it did not have enough information to formulate an operative bidding proposal within the time constraints of the Act's implementation schedule and decided to begin with a more traditional approach based on fixed subsidies and asymmetric regulation.[29]

According to the FCC's *Report and Order on Universal Service*, Incumbent Local Exchange Carriers (ILECs) will maintain most of their current regulatory regime and in particular their COLR obligation. The same per-subscriber subsidy will be paid to any carrier that serves a consumer in a supported area and it will be calculated "by determining the forward-looking economic cost of providing the supported services reduced by a nationwide revenue benchmark calculated on the base of average revenue per line" (par. 223).

This policy, a hybrid between the traditional "regulated monopolist as COLR" and EPOS schemes, has at least one fundamental flaw: it cannot ensure that the support payments in a given area will be "sufficient" as required by the Act. First, regulators would rarely have much information about the cost of serving individual market segments, let alone individual consumers. Their estimates of the "forward-looking economic cost of providing the supported services" will thus be only estimates of the average costs in each given area.[30] If there is enough cost heterogeneity among consumers, "cream-skimming" by competing carriers may push the COLR to serve the relatively more costly consumers. In other words, the COLR's average cost is likely

[28]Paragraph 37, *Notice of Proposed Rule Making and Order Establishing Joint Board*, CC Docket 96-45, March 8 1996.

[29]Ironically, the ensuing controversies over the cost-proxy models to be used in the determination of subsidies have prevented to this day the implementation of this allegedly more traditional policy.

[30]Even that is likely to be a very imprecise estimate. See Dippon and Train (1998) for a glaring example of the unreliability of engineering cost models.

to be higher than the total average cost for the area under consideration. Second, a "nationwide revenue benchmark" may have little to do with the revenues which a carrier can get in any given high-cost area. In sum, neither the cost-estimates, nor the revenue estimates accurately reflect the true costs that a COLR would face in any given high-cost area.

Although the FCC's plan may be a reasonable way to determine the amount of federal support to the States' Universal Service policies, it does not seem appropriate for the actual determination of the support received by any given carrier. That will require, at least, that the "national revenue benchmark" be substituted by the "affordable" price the regulator wants to implement. Even then, the FCC plan would still rely on the imposition of an asymmetric (hence not "competitively neutral") regulatory burden upon ILECs. In passing the Act, however, Congress intended to promote a national policy framework that is not only "pro-competitive", but also "deregulatory."[31] The eventual realization of such intent will require a different subsidization mechanism - perhaps one of those studied in this dissertation.

1.3 A review of the literature

The idea of using auctions as a regulatory tool is definitely not a new one. The seminal paper by Demsetz (1968) showed that franchise auctions can (under some conditions) achieve the second-best average-cost pricing solution for natural monopoly.[32] The problem discussed in this dissertation is, in a sense, the polar opposite of the one considered by Demsetz. First, the regulator can pay firms directly, but cannot grant them protection from competitors in any market.[33] Second, the regulator knows the price it wants consumers to pay, but does not know how much to pay firms for charging such a price.

[31]See H.R. Rep. No. 104-458; Preamble to Pub. L No. 104-104, 110 Stat 56, 1996.

[32]See Harstad and Crew (1999) for a discussion and an extension of Demsetz's model. See Laffont and Tirole (1993) for the mechanism design approach to franchise bidding. Spulber (1989) provides an interesting alternative approach to franchise competition in which the regulator controls the bargaining between consumers and producers.

[33]This case has been studied in the regulation literature, usually under the headings of "by-pass" and "cream-skimming," e.g., see Laffont and Tirole (1993).

The first paper advocating the use of COLR auctions for the allocation of Universal Service subsidies is Salant (1996).[34] Salant's 1996 paper suggested that regulators allocate the COLR obligation and the corresponding subsidies in several service areas using a simultaneous ascending auction format similar to the one used by the FCC for the allocation of spectrum licenses. The main rationale for this choice of auction format was to allow bidders to realize aggregations of service areas that reflected the potential economies of scope across neighboring areas. This concern was also at the base of Kelly and Steinberg's (2000) proposal for a sophisticated implementation of a simultaneous ascending COLR auction with combinatorial bidding.[35]

David Salant later participated in the team of consultants led by Paul Milgrom that developed a proposal for COLR auctions sponsored by GTE Corp. (now Verizon, Inc.) in 1997.[36] The GTE proposal, which the FCC acknowledged as the most complete one in the Universal Service proceedings, called for an original asynchronous sealed-bid format, small service areas, per-subscriber subsidies and an endogenous determination of the number of COLRs in a service area on the basis of the bids submitted.[37]

Milgrom (1997) adopts a mechanism design framework to show how the number of COLRs per service area should be determined as a function of the firms' "bids." The optimal number of COLRs trades off the increased level of (lump-sum) subsidies from appointing more (hence also less efficient) COLRs versus the (assumed) welfare gains from post-auction *competition in the market* among more COLRs.[38] The model does not explain why there would be welfare gains from having more COLRs in a given area. Chapter 4 of this dissertation shows that there may be some welfare gains

[34] Preliminary versions of this paper had been circulated in 1995. Weisman (1989) had already mentioned the possibility of putting the COLR obligation up for auction. Weisman's focus, however, was not on the Universal Service obligation, but on the obligation to provide back-up facilities and the corresponding incentives for network reliability (see also Weisman, 1994).

[35] Preliminary versions of this paper had been circulated in 1997. For a view of the current debate over combinatorial bidding see the papers collected at http://combin.fcc.gov.

[36] The team also included Padmanabhan Srinagesh, Debra Aron and myself. Dennis Weller was the GTE economist responsible for the COLR auction project.

[37] See the Appendix and Weller (1999) for more details.

[38] Milgrom's model, although independently developed, is very similar to Dana and Spier's (1994) model of auctions for licenses. Other papers on regulation with endogenous market structure include Auriol-Laffont (1992), McGuire-Riordan (1995), Riordan (1996), and Wolinsky (1997).

(but at substantially higher costs in terms of subsidy levels) from multiple COLRs if subsidies are paid on a per-subscriber basis. Intuitively, Milgrom's qualitative results, obtained for the case of lump-sum subsidies, should remain true in the case of per-subscriber subsidies, but the adaptation of the model is not straightforward.[39]

Anton *et al.* (1997) also discuss auctions for Universal Service subsidies, but they use a specification of COLRs' obligations that differs from the one used in this dissertation. They assume that the winner of the auction has the obligation to provide service at the same price prevailing in another ("urban") market where, after the auction, the firm may compete Cournot-style with some of the other bidders. This somewhat unrealistic specification[40] can be seen as an attempt to capture in a static framework the regulators' dynamic adjustments of the "affordable price" to the prices charged in low-cost areas and the corresponding reactions of those firms which may be active in both areas. Their results, however, seem quite sensitive with respect to alternative (possibly more realistic) specifications of the model. For example, "a central result of the paper" is that there may be "a perverse incentive for each firm to lose the auction for the rural market in order to gain the more profitable position of serving only the urban market. Equilibrium bidding then leads to a subsidy that compensates for the strategic disadvantage associated with winning. As a result, both firms ultimately benefit and earn the higher profit . . . Further, the urban market has higher prices and lower quantities relative to those of unconstrained oligopoly competition (Cournot) in the urban market" (p. 13). However, if the Cournot game in the urban (low-cost) market is played before the auction and the resulting price is used to define the price constraint in the rural (high-cost) market, there would be no "perverse" incentives in the auction.

[39]Per-subscriber subsidies may induce a monetary externality as firms would prefer that lower subsidies be given to their competitors. This kind of externality is generally ignored in the mechanism design literature, but it has been recognized in some recent work on auction theory; see Engelbrecht-Wiggans (1994), Bulow *et al.* (1999), Ettinger (2000), Maasland and Onderstal (2000).

[40]Firms are unlikely to be asked to submit bids for an obligation that will be fully specified only later as an equilibrium outcome in another market. Moreover, there is no guarantee that the final price will be "just, reasonable, and affordable." Instead, the price constraint for the winner of a COLR auction is specified before bidding occurs.

Finally, Choné *et al.* (2000) consider two different specifications of the Universal Service goal, but their set-up is not compatible with the U.S. Telecommunications Act. Their first specification of the Universal Service goal involves only what they call *ubiquity constraint*: "all consumers should be connected to a network, whatever their location." (p. 250). This does not impose any price ceiling other than consumers' willingness to pay. Their second specification includes both the ubiquity constraint and a *non discrimination constraint*: "the same tariff should be proposed to all those consumers, whatever their location or their connection cost." This specification is similar to the one adopted by Anton *et al.* (1997) and possibly even farther away from the mandate of the U.S. Act.[41] Like this dissertation, Choné *et al.* compare alternative mechanisms for the allocation of Universal Service subsidies. Their focus is on two mechanism: "restricted-entry," in which only the incumbent can receive the subsidy, and "pay or play," which is equivalent to the EPOS schemes considered in this dissertation.[42] Auctions are only briefly mentioned at the end of their paper. They claim that auctions may be less (or more) efficient than "pay or play" depending on the social cost of public funds. However, their result seems to depend on the (implicit) assumption that the source of funding would be different in the two mechanisms: general public funds in the case of auctions and a tax on low-cost (urban) telecommunications markets in the case of "pay or play." Apart from its dubious rationality, this assumption is explicitly ruled out by U.S. Telecommunications Act.

Since this dissertation is about a particular kind of auctions, namely those for universal service subsidies, it is obviously related to the huge literature on auction theory. For a recent general survey and an exhaustive bibliography I refer the reader to Klemperer (2000). The connections of the analysis in this dissertation with the auction theory literature will be noted in the following chapters as the need arises.

[41]Choné *et al.* do not claim otherwise and, of course, one cannot fault (French) authors for not basing their models on U.S. law. It should be noted, however, that their specification of the Universal Service obligation is *not* easier to reconcile with a welfarist approach than the one adopted in the U.S.

[42]Note that the U.S. Act rules out the "restricted-entry" mechanism.

1.4 Plan of the dissertation

The plan of the dissertation is as follows. In chapter 2 I introduce the basic model and find that, in a very wide range of circumstances, auctions achieve the Universal Service goal at lower cost than traditional fixed subsidy schemes. Chapter 3 generalizes the analysis of Chapter 2 by considering durable assets (hence the role of incumbency), unbundling obligations, economies of scope, and incomplete information. The cost advantage of auctions over fixed subsidies is generally confirmed. Chapter 4 shows that COLR auctions may generate insufficient incentives for service quality as price competition at the bidding stage reduces the margins for quality competition after the auction. Chapter 4 also shows that auction designs aimed at improving service quality incentives (by paying subsidies on a per-subscriber basis and appointing several COLRs per area) may be particularly vulnerable to collusive agreements among bidders. Chapter 5 concludes with a summary and some avenues for further research.

Chapter 2

Auctions and Fixed Subsidies: the basic model

2.1 Introduction

In this chapter I take the deregulatory intent of the 1996 Act seriously and provide a comparative analysis of two competitively neutral mechanisms for Universal Service subsidization: *COLR auctions* and what I have called *ex-post open subsidy* (EPOS) or *fixed subsidy* schemes without COLR obligations.[1]

Following the so-called "Wilson doctrine" (i.e., auction/market rules should not depend on the fine structure of beliefs about the players' types), I will only consider *simple* COLR auction formats.[2] Indeed, I will focus on the simplest second-price sealed-bid format: the lowest bidder becomes the sole COLR and receives a subsidy equal to the second-lowest bid; the other bidders get neither subsidies, nor obligations.[3] Sections 2.3 and 2.5 will consider COLR auctions with reserve prices or

[1] I also briefly discuss the case of EPOS schemes with COLR obligations.

[2] Neeman (1999) shows that simple auction formats can be quite effective.

[3] Given the assumptions of the models below, the same results would hold for first-price sealed-bid auctions or ascending auctions. Since one of those assumptions is that of common knowledge among the bidders, the "optimal" (i.e., cost minimizing mechanism) would achieve the first best. If the reader rejects the Wilson doctrine and believes in the mechanism design solution, then he or she already has the answer to the question explored in this chapter: COLR auctions always outperform EPOS schemes – if "suitably" designed. Indeed, regardless of the model's specific assumptions, an

multiple winners.

The choice of simple fixed subsidy schemes as the mechanisms against which COLR auctions are to be compared has a similar motivation. More complicated schemes (e.g., schemes that paid a nonlinear function of the number of subscribers) would be effective only if the mechanism designer (i.e., the regulator) had more knowledge about the industry's cost structure than I am willing to assume.[4]

The two mechanisms will be evaluated mainly on the basis of their ability to achieve the Universal Service goal (i.e., making service available at a price no higher than a specified maximum $\bar{p}$ to everyone in the service area under consideration) at the lowest cost for the regulator.[5]

It is quite obvious that neither mechanism can *always* outperform the other. For example, a COLR auction would be of limited value if only one firm could reasonably offer service in the area and subcontracting was very inefficient.[6] On the other hand, an EPOS scheme based on wildly inaccurate cost estimates may make a COLR auction attractive even with a modicum of potential competition.

It will turn out that, as long as incentives for service quality are not an issue, COLR auctions can very often outperform EPOS schemes. In order to test the limits of this result, I have chosen the basic assumptions of the models used in the comparison to be, if anything, biased in favor of EPOS schemes. In particular, COLR auctions will be compared with an ideal EPOS scheme that pays the lowest possible subsidy which is compatible with the achievement of the Universal Service goal.[7]

Roughly speaking, the relative advantage of COLR auctions with respect to EPOS

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optimal mechanism is always (weakly) better than schemes that, like EPOS schemes, do not try to elicit the firms' private information: the designer need not use that information!

[4]There is, however, an alternative *simple* scheme that deserves to be mentioned: the same per-subscriber subsidy s could be paid only to firms that accept the COLR obligation. This sort of "constrained" EPOS scheme would be equivalent to a COLR auction that appoints a sufficiently large number of winners and sets the reserve price at s. As a consequence, such scheme cannot be considered superior to a "suitably designed" COLR auction. Anyway, I will note in the following where the results derived for "free" EPOS schemes need substantial changes for the "constrained" variety.

[5]But see the remarks at the end of sections 2.3 and 2.4.

[6]But it is shown below that, if consumers are very heterogeneous and have very high value for the service, it could be better than an EPOS scheme even then!

[7]See section 2.4 for the case of partial achievement of the Universal Service goal.

schemes increases with the heterogeneity of consumers, the homogeneity of firms, the share of the potential gains from subcontracting that goes to auction winners, and the value consumers put on the subsidized services. While more precise statements must wait until after the set-up of the model is defined, I anticipate some intuitive arguments for these conditions.

If the minimum cost of service is the same for every consumer, then a uniform unit subsidy equal to the difference between that cost and the regulated price would achieve the first best - unless firms could make more money by forsaking the subsidy and charging high prices to consumers. This suggests that homogeneous consumers that are unwilling to pay very high prices for the subsidized services tend to make EPOS schemes efficient.

If instead there is some consumer h for whom the cost of service is much higher than the average, then h will not be served under an EPOS scheme unless the unit subsidy is at least equal to the difference between the cost of serving h and the regulated price. So consumer heterogeneity is bad for EPOS schemes.

On the contrary, consumer heterogeneity does not matter much for COLR auctions. As shown below, a COLR auction (without subcontracting) will achieve the Universal Service goal with a subsidy equal to the second-lowest average cost minus the regulated price. If firms are sufficiently homogeneous, this will be close to the lowest average cost and thus lower than the minimal EPOS.

Even if firms are not homogeneous, subcontracting may allow every winner of the auction to serve each consumer at close to minimum cost. Bidding competition would then guarantee that the cost savings are passed on to the regulator.

The models in this chapter devote a lot of attention to the possibility of resale or subcontracting.[8] An EPOS scheme can be expected to achieve an efficient allocation: each consumer class is served by the firm that is most efficient at doing so and there is no need for subcontracting.[9] The case is different for COLR auctions. Unless

[8]In fact, they can be read as a contribution to the theory of procurement auctions with subcontracting.

[9]This does not mean that the agent's payoffs under an EPOS scheme never depend on whether subcontracting is feasible. As discussed below, however, the potential effect of subcontracting under EPOS schemes are quite limited.

the same firm is the most efficient provider for each class of consumers, the winner of the auction will benefit from subcontracting to some other firms the production of services for some consumer classes.[10] It seems unreasonable to assume that the opportunity of such savings will always be missed. Indeed, the opposite assumption that all gains of trade will be achieved seems more reasonable and, indeed, so common in the economics literature to be glorified by the (somewhat inappropriate) title of "Coase theorem".[11]

The possibility of subcontracting surely reduces total production costs. The effect on the equilibrium level of subsidies, however, is less clear. Subcontracting increases the payoff from winning the auction, but it also increases the payoff from losing the auction. A firm that loses the auction does not necessarily get zero profits, because it can win some business at the subcontracting stage. The net effect on the equilibrium level of subsidies will depend on what happens at the subcontracting stage. Milgrom (1987) has shown that, in a single-object auction with complete bidder information, the possibility of resale increases the auctioneer's revenue - even if the auction without resale was already efficient. As shown by Haile (1996), this result is not always robust to the introduction of bidders' uncertainty about the private value of the object. Even with completely informed bidders, subcontracting may increase the cost of procurement if the object of the auction is not a single indivisible good. Kamien, Li and Samet (1989) study a procurement auction for an endogenously determined quantity of a perfectly divisible good with two identical and completely informed bidders. They assume that the bidders' (common) cost function is strictly convex (i.e., there are decreasing returns to scale) in order to create a need for subcontracting and show that subcontracting increases the cost of procurement if winning the auction implies a sufficiently large loss of bargaining power

[10] If subsidies are paid on a per-subscriber basis, the winner of the auction would still be the official seller for all consumers. Peha (1999) emphasizes the value of making universal service obligation tradeable among firms. Modulo some differences in transaction costs, it should not matter much whether tradeability is achieved directly or via subcontracting with the sole COLR acting as a reseller.

[11] The classical reference is Coase (1960). Coase only used that assumption to show that, in the absence of wealth effects, it makes "real" allocations unaffected by the initial property rights assignments. Actually, Coase viewed this result as evidence against the usefulness of the "zero transaction costs" assumption.

in the subcontracting stage. The models of this dissertation take the object(s) to be procured as given and (but for Chapter 3) assumes that cost functions are linear,[12] but relaxes several other assumptions of the model by Kamien, Li and Samet (1989). First, the object(s) of procurement are not necessarily identical. Second, the firms may have different technologies. Third, there can be any number of firms. This is actually the most important difference with respect to Kamien, Li and Samet's model, because it hugely increases the range of bargaining structure in the post-auction subcontracting subgame. The model of subcontracting developed in Section 2.2.4 below is sufficiently general to encompass all reasonable structures, yet it provides a well-defined solution that confirms almost all of Kamien, Li and Samet's results.[13]

The plan of the chapter is as follows. The next section sets up the main model and compares EPOS schemes and COLR auctions without reserve prices. The effects of introducing reserve prices in a COLR auction are discussed in section 2.3. Section 2.4 considers the case in which the Universal Service obligation may be only partially satisfied. Section 2.5 considers the possibility of appointing more than one COLR per area.

2.2 The basic model

This section considers the simplest possible COLR auction, namely one that always appoints a single COLR per area and does not impose any maximum bid.[14]

As shown below, the best comparative advantage of EPOS schemes is that they can exploit the potential productive efficiency of *niche* carriers, i.e., firms that may be very efficient at serving a subset of the market in a given area, but very inefficient

[12]Kamien, Li and Samet's assumption of diseconomies of scale is probably appropriate in the context of subcontracting in the manufacturing or construction industries. In the context of COLR auctions, however, the complications are much more likely to arise from economies of scope than from diseconomies of scale. Doing away with the latter, even if not including the former, is therefore a step in the right direction for the purpose of this paper.

[13]The exception is that in the case of three or more bidders, subcontracting may reduce the cost of procurement even if winning the auction implies the loss of *all* bargaining power in the subcontracting stage.

[14]See section 2.3 for a discussion of reserve prices.

at serving the whole area as a COLR. A COLR auction that appoints a single COLR per area cannot do the same very easily.[15]

The absence of a maximum acceptable bid makes the contrast even starker: the comparison is between an EPOS set by a relatively well-informed regulator and a COLR auction designed by a regulator with no information at all.

I will consider only the case of a "purely high-cost" service area, i.e., a service area in which no consumer could be profitably served at the regulated price without a subsidy.[16]

Consider an area that hosts a unit mass of consumers. All consumers have the same demand function: they want one unit of "core services" if the price is v or less, and zero otherwise. Given the Telecommunications Act's requirement that core services be affordable, I will assume that the regulated price $\bar{p}$ is no higher than v, i.e., $\bar{p} \leq v$. Consumers differ in the cost to provide them with such core services. Let $\{q_1, q_2, \ldots, q_M\}$ be the vector of (strictly positive) shares of the M classes of consumers in the area ($\sum_{h=1}^{M} q_h = 1$), N be the number of firms and c_h^f be firm f's (constant marginal) cost of serving a consumer of class h. The firms' cost functions are assumed to be additive both within and across consumer classes, i.e., the total cost of a firm f that serves q_h^f consumers of class h for all h is simply $\sum_{h=1}^{M} q_h^f c_h^f$.[17] For notational simplicity, I will focus on the "generic" case and assume that all c_h^f are different from each other. I will denote by $\eta(h)$ the firm that is most efficient at serving class h and by $c_h^{(i)}$ the cost of serving a consumer of class h for the i-th most efficient firm at doing so.

As mentioned above, I will assume that all consumers are "high-cost": for all f

[15]Whether it can or not depends on the structure of subcontracting (see section 2.2.4). It must be noted that appointing more than one COLR may be of little help anyway (see section 2.5). The relevance of this issue clearly depends on the size of serving areas under consideration – a design dimension not considered here.

[16]If the service area contained also low-cost consumer, COLR auctions for lump-sum and for per-subscriber subsidies would no longer be equivalent. In some cases, it would then be possible to reduce the equilibrium level of subsidies in COLR auctions by paying them on a per-subscriber basis. The presence of low-cost consumers would not affect the size of the unit fixed subsidy necessary to satisfy the Universal Service goal. The restriction to purely high-cost areas is therefore biased against COLR auctions.

[17]See Chapter 3 for the case of subadditive cost functions.

and h, $c_h^f > \bar{p}$. As a consequence, subsidized firms will be the only sellers.[18] The firms' products are perfect substitutes and firms compete in price à la Bertrand.[19]

All this information is common knowledge for the firms, but is ignored by the regulator. The regulator is thus obliged to pay the same subsidy for all consumers if an EPOS scheme is used. I will impose a corresponding constraint on COLR auctions by having a single auction for the whole area.[20]

2.2.1 EPOS schemes without subcontracting

The following proposition establishes a lower bound on the level of EPOS sufficient to satisfy the Universal Service goal, namely the (excess) cost of serving the costliest consumer efficiently.

Proposition 1 *In order to achieve the Universal Service goal, the subsidy paid under an EPOS scheme must satisfy*

$$s^{EPOS} \geq \begin{cases} \bar{c}^{(1)} - \bar{p} & \text{if} \quad v \leq \bar{c}^{(1)} \\ v - \bar{p} & \text{if} \quad \bar{c}^{(1)} \leq v \leq \bar{c}^{(2)} \\ \bar{c}^{(2)} - \bar{p} & \text{if} \quad v \geq \bar{c}^{(2)} \end{cases} \tag{2.1}$$

where $\bar{c}^{(i)} \equiv \max_h c_h^{(i)}$.[21]

Proof:

First, consider the case of high demand, i.e., $v \geq \bar{c}^{(2)}$. Assume that there is a consumer class k such that $s < c_k^{(2)} - \bar{p}$. Clearly, the only firm that might wish to serve k at the regulated price is $\eta(k)$. However, for some sufficiently small ϵ, we have

[18] In the context of this section, this assumption reduces the COLR auction to a standard procurement auction. As far as auctions are concerned, in fact, we could set $\bar{p} = 0$ without further loss of generality.

[19] Cournot competition would lead to higher subsidies in the case of EPOS schemes.

[20] In the procurement context, we might think that the buyer simply does not know how to decompose the system to be procured into its more basic parts. In the context of Universal Service procurement, the "basic parts" are the consumers in the area under consideration. In principle, the regulator could run a separate auction for each consumer in the area.

[21] For future reference, note that the above lower bound can be written as $\bar{c}^{(1)} \vee v \wedge \bar{c}^{(2)} - \bar{p}$.

$\bar{p} + s - c_k^{(1)} < c_k^{(2)} - \epsilon - c_k^{(1)}$. Therefore, $\eta(k)$ will prefer charging class k consumers a price of $c_k^{(2)} - \epsilon$ (which consumers would pay, since it is less than v by assumption) and forsake the subsidy, rather than pricing at $\bar{p}$ and taking the subsidy s. We have thus shown that, unless $s \geq c_h^{(2)} - \bar{p}$ for all h, there will be some consumers (those of class k) that do not have access to core services at the regulated price or less.

Similarly, if $\bar{c}^{(1)} \leq v \leq \bar{c}^{(2)}$ and the subsidy is $s < v - \bar{p}$, then $\bar{p} + s < c_k^{(2)}$. So only $\eta(k)$ is in the game and it will rather price at v than take a price-plus-subsidy of $\bar{p} + s < \bar{p} + (v - \bar{p}) = v$.

Finally, note that, regardless of v, we cannot have $s < c_h^{(1)} - \bar{p}$ for any h because otherwise no firm would be willing to serve consumers of class h.

Q. E. D.

Remark: Under a "constrained" EPOS scheme, i.e., under a scheme that pays the same fixed per-subscriber subsidy to every carrier that accepts the COLR obligation, a subsidy of $\bar{c}^{(1)} - \bar{p}$ may sometimes be sufficient to achieve the Universal Service goal regardless of v. Indeed, an even lower subsidy may sometimes be sufficient. The determination of the minimal "constrained" EPOS, however, would require a much finer knowledge of the industry's cost structure than it is reasonable to assume. Moreover, if such knowledge were available, it is likely that regulation would dominate both COLR auctions and EPOS schemes.

2.2.2 COLR auctions without subcontracting

Consider now a COLR auction without the possibility of subcontracting the production of services to some or all consumers classes. Since all consumers are "high-cost", the winner of the auction, sole COLR and only recipient of subsidies, will not face any competition after the auction and will serve the whole market. Therefore it does not matter whether subsidies are paid on a lump-sum or per-subscriber basis. Since we are also assuming that bidders have complete information, there are no price or efficiency differences at equilibrium between the various standard auction formats and we can restrict our attention to second-price auctions.

Since there is a unit mass of consumers, the cost of the COLR obligation for firm f is then equal to its average cost minus the price it can charge consumers $\sum_{h=1}^{M} q_h(c_h^f - \bar{p})$. In a second price auction, it is a (weakly) dominant strategy for firms to bid their true valuation,[22] so we have

Proposition 2 *If subcontracting is not allowed and firms do not play (weakly) dominated strategies, a COLR auction will be won by the firm with the lowest average cost and the subsidy will be equal to the second lowest average cost*

$$S^{NS} \equiv (\sum_{h=1}^{M} q_h c_h^f)^{(2)} - \bar{p} \tag{2.2}$$

The following consequence is immediate:

Proposition 3 *If there is a consumer that cannot be served for less than the second-lowest average cost, then COLR auctions without subcontracting will require lower subsidies than the optimal EPOS scheme.*

In particular, *the condition above is satisfied if all firms have approximately the same cost structure*, i.e., if there is a sufficiently small ϵ such $| c_h^f - c_h^g | < \epsilon$ for any f, g and h.

Note, however, that unless all firms have the same cost structure or the area is a natural monopoly (i.e., there is a firm f such that $f = \eta(h)$ for all h), COLR auctions without subcontracting will lead to a technologically inefficient outcome, i.e., some or all consumers will not be served by the firm that can do so at lowest cost.

2.2.3 The case of subcontracting

Let us now consider the case of COLR auctions with subcontracting. I will make only *minimal assumptions on the structure of bargaining in the subcontracting game.* There is a finite number of periods $T \geq 2$ available for bargaining. After the T

[22] This is a well-known result that holds true even in incomplete information settings unless firms ignore their own value for the object and this value depends (in a statistical sense) on the other firms' information (see, e.g., Klemperer, 2000).

periods have passed, service must be produced and offered to consumers. In the last period, if firm f has acquired the obligation to serve consumer class h, it has three options. *First*, it can do nothing; it will then produce the service for class h at a unit cost c_h^f. *Second*, it can run a subcontracting second-price auction with reserve price c_h^f.[23] *Third*, it could enter into negotiations with another firm (arguably one that is more efficient at serving class h) to delegate production. If it does so, I assume that the outcome of bargaining will follow a (generalized) Nash solution: a subcontracting agreement will be signed whenever it is efficient to do so and firm f will get a fraction $\alpha \in [0, 1]$ of the potential gains from trade.[24] If f has the obligation to serve several classes, it can enter into separate negotiations with more than one other firm, but cannot negotiate (in the last period) over the same class with more than one firm.[25] For simplicity, I also assume that if two firms bargain over several consumer classes in the last period, then the outcome of bargaining is the same as if they bargained separately for each class.[26]

In the penultimate period, firms must be able to run subcontracting auctions as in the last period, but *I do not impose any restrictions on the kind of messages and contracts that can be signed in the penultimate or any other bargaining period.*[27] I do assume, however, that no firm can credibly commit to play dominated strategies in any subgame of the subcontracting game.[28]

Finally, I assume that there is no discounting. If a subcontracting game satisfies

[23]Actually, the proposition below holds also if auctions are not allowed in the last period. As noted above, given the assumption of complete information, a first-price auction would lead to the same results. The restriction on the reserve price is not essential and is assumed only to avoid assuming implicitly that the winner of the COLR auction could get all the bargaining power. If that was the case, then (as shown below) COLR auctions would always be better than EPOS schemes.

[24]But see the remark after the following proposition for an interpretation of α that allows for inefficiencies in bargaining.

[25]The assumption that the negotiations be *separate* is another limit on the bargaining power of the subcontracting "buyer" and, as such, it does not favor COLR auctions.

[26]If $\alpha = 0.5$ this would follow from the properties of the (generalized) Nash bargaining solution. The complications for other values of α arise when both bargaining parties have something to buy from the other (e.g., firm f must serve class h and firm g must serve class k, but f is the most efficient provider for k and g is the most efficient provider for h).

[27]In fact, any such restrictions would be irrelevant anyway.

[28]This is in the spirit of Milgrom (1987). Jehiel and Moldovanu (1999) also adopt a similar framework.

these conditions, I will refer to it as *"Sufficiently Rich and Fast"* or as satisfying condition *SRF.*

We then get the following

Proposition 4 *Consider a second-price COLR auction followed by a subcontracting game satisfying SRF. In all sub-game perfect equilibria, all firms will bid the same amount, which then equals the level of subsidy:*

$$S^{COLR} = \sum_{h=1}^{M} q_h[\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)}] - \bar{p}. \tag{2.3}$$

Proof:

Let $V(f,h,t)$ be firm f's unit cost of the obligation to provide service for class h when there are $T-t$ periods left for subcontracting arrangements.[29] Clearly $V(\eta(h),h,t) = c_h^{\eta(h)} \equiv c_h^{(1)}$ for any (h,t) and $V(f,h,T) = c_h^f$ for any (f,h).

In the last period ($t = T-1$), if $f \neq \eta(h)$ has acquired the obligation to produce service for class h, it can fulfill the obligation by negotiating directly with $\eta(h)$ and paying $[\alpha c_h^{(1)} + (1-\alpha)c_h^f]$ per consumer.[30] Alternatively, f can run an auction: everyone would bid $V(f,h,T) = c_h^f$ and the price would be $c_h^{(2)}$.[31] It is easy to show that bundling several classes into a unique subcontracting auction cannot improve f's payoffs. We thus have that for all h and for all $f \neq \eta(h)$

$$\begin{aligned} V(f,h,T-1) &= c_h^f \wedge c_h^{(2)} \wedge [\alpha c_h^{(1)} + (1-\alpha)c_h^f] \\ &= c_h^{(2)} \wedge [\alpha c_h^{(1)} + (1-\alpha)c_h^f]. \end{aligned} \tag{2.4}$$

[29] In principle, this "value functions" could depend on which firms have the obligation to provide service for the other consumer classes. It is shown below that the assumptions on last-period bargaining ensure that this is not the case.

[30] Negotiating directly with any other firm would lead to lower payoffs. Recall that, by assumption, the outcome of last-period bargaining over a given consumer class is independent of bargaining over other classes.

[31] Recall that the reserve price in a subcontracting auction is assumed to be equal to the buyer's own cost.

The second lowest cost among $\{V(f,h,T-1)\}_{f=1}^{N}$ is $\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)} \equiv p_h$. This is also the unit price in an auction for h at the penultimate subcontracting period.

Note that $\eta(h)$ can always guarantee itself a price at least as high as p_h just by refusing to enter into any negotiation until the last subcontracting period. On the other hand, every other firm can guarantee itself to pay no more than p_h by running an auction in the penultimate subcontracting period. Therefore, the COLR's actual cost of serving a class of consumers h for which it is not the most efficient provider is always p_h and this does not depend on what happens with the other classes.

The total cost of the COLR obligation for firm f is therefore

$$\sum_{h\in\eta^{-1}(f)} q_h c_h^{(1)} + \sum_{h\notin\eta^{-1}(f)} q_h[\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)}] - \bar{p} \tag{2.5}$$

.

Similarly, if firm f loses the auction, it will get a total profit equal to

$$(1-\alpha)\sum_{h\in\eta^{-1}(f)} q_h[c_h^{(2)} - c_h^{(1)}] \tag{2.6}$$

Let us go back to the (main) procurement auction. Firm f will bid the difference between its profits in case of loss and its profits (net of the subsidy) in case of victory in the auction.[32] This is equal to the sum of the amounts in equations (2.6) and (2.5). A little algebra shows that this sum does not depend on f and is indeed equal to (2.3).

Q. E. D.

Remark: The above formula may be valid *even if last-period bargaining is not always efficient.* For example, assume that there is a probability β that last-period negotiations fail and that, if they don't fail, the outcome is as before. Then the expected cost of the obligation to serve h for the second most efficient firm at doing

[32]Recall that this is a procurement auction, so the bids represent money that the bidders would receive from the auctioneer.

so would be

$$\begin{aligned}\tilde{p}_h &= \beta c_h^{(2)} + (1-\beta)p_h \\ &= \alpha(1-\beta)c_h^{(1)} + [1-\alpha(1-\beta)]c_h^{(2)}\end{aligned}$$

If the firms are risk-neutral, then the above proof shows that (2.3) would still hold with $\tilde{\alpha} = \alpha(1-\beta)$ instead of α.

Remark: The requirement that there are at least two periods for subcontracting is necessary in order to ensure that there is enough time to get the object to the firm with the second-lowest cost and to allow that firm to negotiate with the most efficient firm.

Remark: Note that, in this model, the equilibrium level of subsidies does not depend on whether the regulator runs an auction for each consumer class or bundles several consumer classes together.

Remark: Note that *if there are more than two firms, subcontracting could reduce procurement costs even if* $\alpha = 0$.[33] As in Kamien, Li and Samet (1986), this is not possible when there are only two firms.

The argument used in the proof can also be applied to the analysis of EPOS schemes with efficient subcontracting. If firms can sign binding contracts with consumers that specify the price, time of delivery, and sufficiently heavy penalties for non-compliance, then prices will be driven down to $p_h \wedge v - s$, so that the minimum EPOS is $\max_h(c_h^{(1)} \vee v \wedge p_h) - \bar{p}$. However, if long-term contracts with consumers entail excessive transaction costs, the dynamics of competition under EPOS schemes may also be unaffected by the possibility of subcontracting.

We can summarize the results of this section as follows. Suppose subcontracting is "Sufficiently Rich and Fast." Then, when subcontracting does *not* affect competition under EPOS schemes, COLR auctions are a more efficient Universal Service

[33] For example, consider the case in which $N = M = 3$, $q_1 = q_2 = q_3 = 1/3$, and the firms' cost vectors are $c^1 = \{1, 2, 96\}$, $c^2 = \{96, 1, 2\}$ and $c^3 = \{2, 96, 1\}$. With $\alpha = 0$, the subsidy would be equal to 2 with efficient subcontracting and equal to 33 without subcontracting.

subsidization mechanism than EPOS schemes if and only if

$$\sum_h q_h[\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)}] \leq (\max_h c_h^{(1)}) \vee v \wedge (\max_h c_h^{(2)}) \tag{2.7}$$

When subcontracting *does* affect competition under EPOS schemes, COLR auctions are a more efficient Universal Service subsidization mechanism than EPOS schemes if and only if

$$\sum_h q_h[\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)}] \leq \max_h(c_h^{(1)} \vee v \wedge [\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)}]) \tag{2.8}$$

In particular, we have

Proposition 5 *If subcontracting is "Sufficiently Rich and Fast," sub-game perfect equilibria of COLR auctions without reserve prices achieve the Universal Service goal at lower cost than the optimal EPOS scheme if at least one of the following (sufficient but not necessary) conditions is satisfied:*

1. *the buyer of subcontracting services gets a sufficiently high share of the potential gains from trade, or*

2. *consumers put a sufficiently high value on the subsidized services, or*

3. *the minimum cost of serving the most expensive consumer* $(\max_h c_h^{(1)})$ *is higher than the average cost of all consumers when served by their second-best provider* $(\sum_h q_h c_h^{(2)})$.

The latter condition can be interpreted as requiring that consumers are sufficiently heterogeneous (in the minimum cost of serving them) with respect to the firm's heterogeneity (in the cost of serving the various consumer classes). This confirms the result obtained in section 2.2.3: *if all firms have approximately the same cost structure, then a COLR auction with or without subcontracting will be cheaper than the optimal EPOS scheme.*

The efficiency of subcontracting implies that both COLR auctions and EPOS schemes are technically efficient (i.e., the service of each consumer class is produced by the firm that is most efficient at doing so) and satisfy the Universal Service obligation. If the regulator does not have any redistributive goal beyond the Universal Service one, the mechanism that requires the lowest level of subsidy is the one to be preferred.

Consumers, however, are definitely worse off with COLR auctions because they all pay $\bar{p}$ and cannot appropriate the excess subsidy for their class with respect to the costliest class.

The situation for firms is ambiguous. If the non-negativity constraints on price are not binding, the firms get total profits equal to $\sum_h q_h(\bar{p} \wedge (c_h^{(2)} - s^{EPOS}) + s^{EPOS} - c_h^{(1)})$ under an EPOS, while they get $(1-\alpha)\sum_h q_h(c_h^{(2)} - c_h^{(1)})$ under a COLR auction. Note, however, that *if α or v are sufficiently high*, then both profits and consumer surplus are lower under a COLR auction.[34] In this case, *a sufficient condition for the superiority of COLR auctions is that the shadow value of public funds be higher than the welfare weights of both consumers and firms in the area.*[35]

2.3 COLR auctions with reserve prices

The analysis so far has not considered the possibility of imposing a reserve price in the COLR auction. It may be tempting to assert that a COLR auction with reserve price equal to s would always be (weakly) cheaper than a fixed subsidy of s.[36] Actually, it would, but at a price: if the reserve price is set too low, there could be no participation in the auction, hence no COLR and universal lack of service in the area.[37] For example, assume that there are two firms and two consumer

[34] If α is close to one, a COLR auction drives total profits close to zero. If v is high enough, $s^{EPOS} = \max_h c_h^{(2)} - \bar{p}$ and total profits under the optimal EPOS scheme are $\sum_h q_h(c_h^{(2)} - c_h^{(1)}) \geq (1-\alpha)\sum_h q_h(c_h^{(2)} - c_h^{(1)})$.

[35] If the shadow value of public funds is lower than that, then the regulator should simply transfer money to firms and consumers in the area until the condition is satisfied.

[36] Ausubel and Cramton (1999b) show that generalized Vickrey auctions with suitably chosen (individualized) reserve prices are revenue-maximizing if, as assumed here, resale markets are efficient. In the context of their model, however, the latter condition is quite restrictive. More importantly, the optimal choice of reserve prices depends on the auctioneer's beliefs over the firms' types and is thus incompatible with the Wilson's doctrine.

[37] Note that this problem also affects "constrained" EPOS schemes. Of course, if s is low enough, even "free" EPOS schemes will result in universal lack of service, but their performance degrades more gracefully (see the following section).

classes. Let $q_1 = q_2 = 0.5$, $\bar{p} = 0$, $\alpha < 1$, $v = c_1^1 = c_2^2 = 1$, $c_2^1 = c_1^2 = 2$; then the best EPOS pays a subsidy $s = 1$. But no firm will participate in a COLR auction with reserve price equal to 1 because the cost of the COLR obligation is $0.5 \cdot 1 + 0.5 \cdot [\alpha \cdot 1 + (1 - \alpha) \cdot 2] = 1 + (1 - \alpha)/2 > 1$.

This example has two interesting features. First, the efficient market structure has more than one active firm (i.e., it is not a case of natural monopoly). Second, firms rank consumers in opposite ways. The following proposition shows that these conditions are necessary for EPOS schemes to outperform COLR auctions with reserve prices.

Proposition 6 *A COLR auction with reserve price $s \geq \max_h c_h^{(1)} - \bar{p}$ can achieve the Universal Service goal if at least one of the following conditions holds:*

1. *the winner of the COLR auction can appropriate a sufficiently high share of the gains from subcontracting trade (e.g., $\alpha = 1$ in SRF subcontracting);*
2. *the most expensive consumer in the efficient market structure is also the most expensive consumer for the firm who is most efficient at serving him, i.e. $k \equiv argmax_h c_h^{\eta(h)} = argmax_h c_h^{\eta(k)}$.*

Proof:

A COLR auction always achieves the Universal Service goal, provided that there is at least one firm that participates in the auction. Therefore it is enough to show that, under each of the conditions of the proposition, there is an equilibrium in which the auction does not go empty. Without loss of generality, assume that $\bar{p} = 0$.

The sufficiency of the first condition is trivial: $\alpha = 1$ implies that the cost of the COLR obligation is the minimum possible, hence no higher than the cost of serving the most expensive consumer.

If the second condition is satisfied, then $\max_h c_h^{\eta(k)} \geq \sum_h q_h c_h^{\eta(k)}$. But the latter is the cost of the COLR obligation for firm $\eta(k)$ in the case in which she does not use subcontracting. Therefore, if nobody else participates in the auction, firm $\eta(k)$ will (weakly) prefer to participate.

Q. E. D.

Remark: The second condition does not depend on whether subcontracting is feasible. It is trivially satisfied if the area is a natural monopoly ($\eta(h)$ is constant in this case) or if all firms rank consumers' costliness in the same way (i.e., if there is an ordering of consumers such that c_h^f is increasing in h for all f).

Remark: In a model with a continuum of consumer classes, then there is another sufficient condition for participation in the COLR auction with reserve price $s \geq \max_h c_h^{(1)} - \bar{p}$: it would be enough to assume the efficiency of subcontracting and the existence of an ordering of consumers such that $c^{(1)}(h)$ and $p(h) = [\alpha c^{(1)}(h) + (1-\alpha)c^{(2)}(h)]$ are both continuously non-decreasing in h and that $\eta(h)$ is continuous almost everywhere.[38]

There is one important caveat to the above proposition: it only guarantees the existence of *one* equilibrium such that there is participation in the auction. It can be shown that, if the reserve price is binding, then every firm will prefer to act as a subcontractor to the COLR rather than being the COLR herself. There will then be mixed strategy equilibria in which the auction will go empty with positive probability.

Finally, it must be noted that the introduction of reserve prices weakens one of the most important comparative advantages of COLR auctions with respect to EPOS schemes, namely the possibility of doing without expensive estimates of firms' costs. It does not eliminate it completely, though. The regulator that adopts a COLR auction can rely on less precise cost estimates and be relatively "generous" in setting reserve prices, since there is a chance that competition will make them non-binding and bring down the level of subsidies. EPOS schemes, on the contrary, do not have any mechanism to bring subsidies down if the cost estimates were too pessimistic.[39]

[38]The sketch of the proof is as follows. Without loss of generality, we can assume that $q(h) = 1$. Let $f = \eta(1)$. Let t be the highest consumer at which $\eta(h)$ changes (if there isn't any such t, then the area is a natural monopoly and the proposition in the text applies). By continuity, $c^f(t) = c^{\eta(t)}(t) = p(t)$. Since $p(t)$ is increasing, $\max_h c^{(1)}(h) = c^f(1) \geq c^f(t) = p(t) \geq p(v)$ for all $v < t$. Therefore, the cost of the COLR obligation for firm f is less than the reserve price and f will participate if nobody else does.

[39]It should also be noted that the two subsidization mechanism require different kinds of cost estimates: average costs to set reserve prices in COLR auctions and "maximal" costs to set EPOS levels. It is not clear which information would be easier to obtain.

2.4 Insufficient subsidies and partial COLR obligations

It may be argued that it is unreasonable to consider only uniform subsidies so high that *every* consumer in the area would be offered service at the regulated price. If there were only one very high cost consumer, it would not make sense to subsidize everyone at that same high level. In other words, it may be more reasonable to assume that the regulator has a less extreme social welfare function and is willing to trade-off a slightly less-than-Universal Service for a large reduction in the subsidy cost and in the misallocations that are caused by its financing.

On the other hand, if we consider the possibility of satisfying the Universal Service obligation only partially, we must do so in a way that maintains a level playing field between COLR auctions and EPOS schemes. One such way is to modify the COLR obligation by allowing the COLR to deny service to a given number of consumers. If $Q(s)$ is the number of consumers that are served when we set a fixed subsidy equal to s, then the natural comparison is with a COLR$(Q(s), s)$ auction, i.e. with a COLR auction in which the winner can refuse service to at most $1 - Q(s)$ consumers and in which the reserve price is equal to s.

A general analysis of such an auction is quite messy. However, proposition (6) can be extended to the present context at the sole price of a more awkward wording.

Proposition 7 *In all pure strategy equilibria, at least one firm will participate in a COLR($Q(s), s$) auction if at least one of the following conditions hold:*

1. *the winner of the COLR auction can appropriate a sufficiently high share of the gains from subcontracting trade (e.g., $\alpha = 1$ in SRF subcontracting);*
2. *There are at least $Q(s)$ consumers h such that $c_h^{\eta(k(s))} \leq c_{k(s)}^{\eta(k(s))}$ where $k(s)$ is the $Q(s)^{th}$ most expensive consumer in the efficient market structure, i.e., the consumer that would be marginal under an EPOS equal to s.*

The proof is practically identical to the one of proposition (6) and is therefore omitted.

The assumption that the regulator knows the function Q is not very realistic. Of course, the right comparison of these subsidization mechanisms should be made by formulating a general environment that captures the regulator's goals and beliefs. Such a model, leaving aside the role of reserve prices, would be reminiscent of Weitzman's (1974) analysis: EPOS schemes fix prices, while partial-COLR auctions fix quantities.[40]

2.5 Multi-COLR auctions

One of the necessary conditions for COLR auctions with reserve prices to fare worse than EPOS schemes is that the efficient market structure calls for more than one active firm. The kind of COLR auctions considered so far always appoint a single COLR per area. It may be thought that this is an unnecessary limitation and that one could improve the performance of the auction by trying to appoint a number of COLRs equal to the number of active firms in the efficient market structure. Unfortunately, this is unlikely to be the case.

The analysis of multi-COLR auctions becomes quite complicated if subsidies are paid on a per-subscriber basis.[41] In the rest of this section, I will consider the case of lump-sum (per-area) subsidies only.

If subsidies are paid on a lump-sum basis, the problem of assigning consumers to COLRs becomes obviously crucial. If the regulator could rely on customers going to the COLRs that are most efficient at serving them, then the appointment of the right number of COLRs would surely help. Although not uncommon in the industrial organization literature, it is unreasonable to assume that consumers will have the knowledge and the inclination to distribute themselves efficiently.[42] It is much more

[40] One could also consider hybrid mechanisms. For example, one may set a relatively low EPOS *and* run a COLR auction (possibly with a very high reserve price).

[41] See Chapter 4 for a discussion of per-subscriber subsidies.

[42] Since all consumers are high-cost, each COLR will do its best to convince consumers to go elsewhere. This is why multi-COLR auctions for lump-sum subsidies are definitely not to be recommended if service quality is not verifiable. It must be pointed out, however, that the problem is only mitigated, but not solved by paying per-subscriber subsidies: unless the subsidy is so high that every consumer becomes profitable, there will always be consumers that COLRs try to avoid (see

sensible to assume that consumers will be matched to COLRs in a purely random fashion and that it will be the COLRs' responsibility to subcontract them when possible and necessary. If that is the case, then appointing more than one COLR is not going to help at all.

Proposition 8 *Consider a COLR auction for lump-sum subsidies that appoints $n < N$ COLRs per area and does not impose a reserve price. Assume that there is a continuum of consumers in each class and that, after the auction, consumers will be assigned to COLRs in a random uniform manner (i.e., each consumer is assigned to any given COLR with probability $1/n$).*[43] *Then, both with and without (SRF) subcontracting, the total level of Universal Service subsidies in any subgame perfect equilibrium is lowest when $n = 1$, i.e., when the auction appoints a single COLR.*

Proof:

If subcontracting is not allowed, then the presence of $(n-1)$ other COLRs means that the expected cost of the COLR obligation for any given firm is just $1/n$ times that firm's cost of serving the whole area. Therefore, in a uniform $(n+1)^{th}$ price auction, firms will bid $1/n$ times their average cost and the subsidy level will be equal to $1/n$ times the $(n+1)^{th}$ highest average cost.[44] Since the subsidy will be paid to n firms, the total cost to the regulator will be equal to the $(n+1)^{th}$ lowest average cost. This is obviously minimized when $n = 1$.

Consider now the case of efficient subcontracting. If a firm f loses the auction, its profits are

$$(1-\alpha) \sum_{h \in \eta^{-1}(f)} q_h [c_h^{(2)} - c_h^{(1)}] \tag{2.9}$$

regardless of n. If it wins the auction and becomes one of the COLRs, then it will have to serve a fraction $1/n$ of the consumers; it will serve directly those for which it

Chapter 4).

[43] This is not entirely rigorous (because of measurability problems with continuum of random variables), but it is a good approximation.

[44] The results would be essentially unchanged in the case of any other standard auction.

is the most efficient provider and subcontract the rest for a total cost of

$$\frac{1}{n}(\sum_{h\in\eta^{-1}(f)} q_h c_h^{(1)} + \sum_{h\notin\eta^{-1}(f)} q_h p_h - \bar{p}). \tag{2.10}$$

But a COLR will also profit from selling subcontracting services to other COLR for a total gain of

$$\frac{n-1}{n}(1-\alpha)\sum_{h\in\eta^{-1}(f)} q_h[c_h^{(2)} - c_h^{(1)}]. \tag{2.11}$$

The total opportunity cost of becoming a COLR (and hence firm f's bid in the second-price auction) is equal to the sum of the first two term minus the the last one. That is equal to

$$\frac{1}{n}(\sum_h q_h p_h - \bar{p}). \tag{2.12}$$

Once again, this is independent of f and equals the subsidy to be paid to each COLR. Since there are n COLRs, the total cost to the regulator is

$$\sum_h q_h p_h - \bar{p}. \tag{2.13}$$

This is entirely independent of n.

Q. E. D.

2.6 Conclusion

The main contribution of this chapter is the development of a basic model of procurement auctions with subcontracting and its use in the first comparative analysis of (COLR) auctions as (Universal Service) subsidization mechanisms. COLR auctions have been shown to improve upon the "classical" fixed subsidy mechanism for a very wide range of demand and cost structures.

The models developed in this chapter share several simplifying assumptions: bidders have complete information, there are no economies of scope or sunk costs, quality of service is fixed, and the game is played only once. The following chapter shows that the first two of those assumptions can be removed without altering the nature of the results presented here. If collusion among bidders can be ruled out, the results are also shown to be qualitatively robust to the introduction of non-trivial dynamics. However, as shown in Chapter 4, if collusion is possible or if quality of service can vary in a manner that is not verifiable by the regulator (and especially if both conditions are satisfied), the design of effective COLR auctions is considerably more delicate.

Chapter 3

Extensions of the basic model

3.1 Introduction

The previous chapter provided a first comparison of COLR auctions and EPOS schemes employing a series of simplifying assumptions. There I argued that the choice of assumptions was made with a view to avoid biasing the results in favor of COLR auctions. In this chapter, I provide some justification for that claim and show that the results obtained so far are qualitatively robust to a variety of alternative assumptions about the nature of the firms' information and cost structures.

First, I consider the fact that serving a consumer may require not only some variable (per period) costs, but also investments in durable assets. Moreover, for many consumers, there will be one firm (and probably only one firm) that already owns such assets. In section 3.2, I derive the corresponding equilibrium level of subsidies in the cases where those assets are either perfectly transferable across firms or fully sunk. Among other results, I show that sunk costs may lead to technically inefficient outcomes under COLR auctions even if subcontracting is reasonably (but not completely) efficient. In the same section, I study the effect of introducing the obligation for the incumbent to grant competitors access to its (transferable) assets at regulated prices. Such an obligation is actually present in the U. S. regulatory environment, where incumbent local exchange carriers must provide access to (practically all of) their "unbundled network elements" or *UNEs*.[1] I will thus refer to this obligation as the "unbundling obligation" and show that, somewhat surprisingly, it may actually benefit the incumbent.

In Section 3, I return to a static one-period model like the one studied in Chapter 2, but I allow the firms' cost functions to exhibit economies of scope across consumer classes. Since the general case is too complex to allow the derivation of explicit closed form solutions, I only consider the simplest form of economies of scope, namely the presence of a fixed per-area cost. I show that it is unlikely (though theoretically possible) that COLR auctions lose any comparative advantage with respect to EPOS schemes because of cost subadditivity. I also show that, in some cases, the introduction of small fixed (per-area) costs may improve the comparative performance of COLR auction precisely when there are "niche" carriers, i.e., carriers that are very efficient at serving some consumer class, but very inefficient at serving the other classes. With additive costs, instead, the presence of "niche" carriers tends to favor EPOS schemes.

Finally, in Section 4, I weaken the assumption that firms are perfectly informed about their rival's costs even before the auction. In particular, I consider a simple symmetric model with two firms and two consumer classes in which firms have the same commonly known cost of serving one of the two consumer classes (a different one for each firm), but have private information about their cost of serving the other class. I derive the equilibrium bid functions and the expected level of subsidies and prove that first-price and second-price auctions are revenue equivalent in this model. The comparison with EPOS schemes does not show any new qualitative result.

3.2 Incumbency and unbundling obligations

The provision of basic telephony service requires large investments into long-lasting assets (e.g., loops and switches) that have little value for other uses. These assets, however, do not necessarily represent sunk costs at the firm level, because they can

[1] See Section 251 of the Telecommunications Act.

be sold (or leased) to other carriers.[2]

This section extends the analysis in Chapter 2 by taking into account such investments. In particular, I assume that the provision of service to a customer of class h requires a long-lived asset that costs K_h, in addition to the per-period costs c_h^f.[3] For simplicity, I assume that the assets are infinitely-lived (not subject to depreciation) and either fully transferable or fully sunk. I also consider only assets and costs that are specific to single consumers and/or to "consumer classes."[4] In order to study the role of incumbency, I will allow the possibility that some firms may own such assets for some or all consumers already before the first auction. Finally, I will consider only non-collusive equilibria by focusing on Markov-perfect equilibria and assuming that firms cannot commit to multi-period contracts.[5]

The problem of transferring existing assets from incumbents to entrants is one of the thorniest issues in the debate about franchise bidding.[6] Unlike the recent valuable contributions by Stole (1994) and Harstad and Crew (1999), the mechanism I consider does not attempt to affect asset ownership directly, but leaves that to free bargaining by interested parties.

3.2.1 Transferable assets

This section will deal with the case of assets that are perfectly transferable across firms. This may be a reasonable assumption if all firms share the same technology and can thus easily incorporate other firms' assets into their network. The next section will examine some of the issues raised by firm-specific (sunk) assets.

[2] "A machine will be labeled a fixed cost if the firm rents it for a month (or can sell it without capital loss a month after its purchase) and a sunk cost if the firm is stuck with it." (Tirole, 1988, p. 308).

[3] I will abuse notation by using K_h for both the asset itself and for its cost. Note that the cost of the assets are the same for all potential entrants. Allowing K_h to depend on f would only make the algebra considerably more complicated.

[4] See next section for the analysis of COLR auctions and EPOS schemes when there are economies of scope across classes of consumers.

[5] See Chapter 4 for a discussion of collusion in COLR auctions.

[6] Note, however, that the goal here is to compare two deregulated market mechanisms (COLR auctions and EPOS schemes), not to compare markets with regulation.

In the case of transferable assets, it is possible to provide service not only by building or buying the asset, but also by leasing the asset for one or more periods at the time.[7] It can be shown that allowing for the possibility of leasing does not change the result of the analysis, so I will focus mainly on the make-or-buy choice.

I maintain the assumptions on subcontracting made in Chapter 2, but now they apply to both the variable cost component of service and the fixed asset. Consideration of capital assets, however, requires a specification of the timing of subcontracting over asset sales and service production. In particular, I will assume that if bargaining initially ends in disagreement and an entrant builds (duplicate) facilities, there is still time to bargain over the transfer of service production.[8] Finally, I will assume that firms that own an asset K_h cannot (be induced to) destroy it, nor can they sell it to another firm that already owns the same kind of asset. By analogy with the terminology of Chapter 2, I will refer to the above assumptions as characterizing a *"Sufficiently Rich and Fast (SRF) bargaining over assets and production."*

Model set-up

I consider an infinite sequence of "periods" with one COLR auction per period. I assume that all parties discount the future using the same (commonly known) discount factor $\delta \in [0, 1)$ per period, but there is no discounting within periods.[9] I will only consider Markov-perfect equilibria of the dynamic game whose state is defined by the firms' asset ownership profiles $x = \{x_h^f \in \{0, K_h\}\}_{h \in H}^{f \in F}$.[10]

For simplicity of exposition, I will begin with the simplest possible case and assume that there are only one consumer and two firms, the incumbent I and an entrant E.[11]

[7] In practice, however, leasing the incumbent's assets for one period may not be an efficient contractual arrangement because of moral hazard considerations (e.g., with regard to care and maintenance of the assets).

[8] This is actually equivalent to the assumption that procurement of the asset cannot be instantaneous and simultaneous with the provision of service.

[9] This seems a reasonable assumption if the time between auctions is long with respect to the time it takes to run the auctions and conclude subcontracting arrangements.

[10] The Markov restriction rules out collusive equilibria. For sufficiently high discount factors, by the folk theorem, the model may have many other (non-Markov) equilibria and, in particular, "collusive" ones. I leave the study of collusion in COLR auctions for Chapter 4.

[11] Since there is only one consumer, I drop the corresponding subscript from the notation.

The firms' variable costs are c^I and c^E and the cost of the asset is K. The regulated price is assumed to be zero, without loss of generality.

There are four possible states: $x = (0, 0)$, in which nobody owns the asset, yet; $x = (K, 0)$, in which the incumbent is still the only firm which owns the asset; $x = (K, K)$, in which both firms own assets (i.e., the entrant procured the asset in some previous period); $x = (0, K)$, in which only the entrant owns the asset (i.e., the entrant bought the incumbent's asset in some previous period).[12] The total profit of firm f in state (x^I, x^E) are denoted by $\pi^f(x^I, x^E)$.

The case of duplicate facilities

Given the no-disposal assumption, $x = (K, K)$ is an absorbing state. The analysis of Chapter 2 and the Markovian restriction give us

$$\pi^f(K, K) = \frac{1}{1-\delta}(1-\alpha)(c^{(2)} - c^f)^+ \tag{3.1}$$

and

$$s(K, K) = \frac{1}{1-\delta}[\alpha c^{(1)} + (1-\alpha)c^{(2)}] \tag{3.2}$$

The case of one efficient incumbent

Consider now the case $x = (K, 0)$ when $c^I < c^E$. If the entrant has won the auction at a subsidy level equal to s, efficiency requires that the entrant subcontracts production to the incumbent. Letting p_S denote the subcontracting price, we have that the firms' payoffs in the efficient outcome are

$$\mathit{Eff} = \{p_S - c^I + \delta\pi^I(K, 0); s - p_S + \delta\pi^E(K, 0)\}$$

In case of disagreement, the entrant would procure the asset at cost K and then bargain again to subcontract production. Since the state would then be $x = (K, K)$,

[12] I refer to firm I as the incumbent even in this third case, even though the term "original incumbent" would be more precise.

the disagreement payoffs would be

$$\begin{aligned} Dis &= \{(1-\alpha)(c^E - c^I) + \delta\pi^I(K,K); \\ &\quad s - K - \alpha c^I - (1-\alpha)c^E + \delta\pi^E(K,K)\} \end{aligned}$$

The potential gains from trade are

$$GT = K + \delta[\pi^I(K,0) + \pi^E(K,0) - \pi^I(K,K) - \pi^E(K,K)]$$

Assume for the moment that

$$\Delta_1 \equiv \pi^I(K,0) + \pi^E(K,0) - \pi^I(K,K) - \pi^E(K,K) \geq 0$$

This will be shown to be true in equilibrium and guarantees that the gains from trade are positive. The subcontracting price that gives a share $(1-\alpha)$ to the subcontractor (i.e., in this case, the incumbent) is

$$p_S = \alpha c^1 + (1-\alpha)c^E + (1-\alpha)K + \delta\pi^I(K,K) + (1-\alpha)\delta\Delta_1$$

The firms' profits are

$$\begin{aligned} \pi_L^I(s) &= (1-\alpha)(c^E - c^I) + (1-\alpha)K + \delta\pi^I(K,K) + (1-\alpha)\delta\Delta_1 \\ \pi_W^E(s) &= s - \alpha c^1 - (1-\alpha)c^E + \delta\pi^E(K,0) - (1-\alpha)\delta\Delta_1 \end{aligned}$$

If the incumbent wins the auction there is no scope for subcontracting and profits are

$$\begin{aligned} \pi_W^I(s) &= s - c^I + \delta\pi^I(K,0) \\ \pi_L^E(s) &= \delta\pi^E(K,0) \end{aligned}$$

In a second price auction, a firm's bid is the level of subsidy at which the firm is indifferent between winning and losing the auction:

$$\begin{aligned} b^I &= \pi_L^I(s) - (\pi_W^I(s) - s) \\ &= p_S \\ &= \pi_L^E(s) - (\pi_W^E(s) - s) \\ &= b^E = s \end{aligned}$$

The firms' total payoff must then solve the following equations

$$\begin{aligned} \pi^I(K,0) &= (1-\alpha)(c^E - c^I) + (1-\alpha)K + \delta\pi^I(K,K) + (1-\alpha)\delta\Delta_1 \\ \pi^E(K,0) &= \delta\pi^E(K,0) \end{aligned}$$

Since $\delta \in [0,1)$ by assumption, we have $\pi^E(K,0) = 0$. Using the already known values for $x = (K,K)$ we can thus solve for $\pi^I(K,0)$

$$\pi^I(K,0) = \frac{1-\alpha}{1-\delta}(c^E - c^I) + \frac{1-\alpha}{1-\delta(1-\alpha)}K \tag{3.3}$$

and for the level of (per-period) subsidies s

$$s(K,0) = \alpha c^I + (1-\alpha)c^E + \frac{(1-\alpha)(1-\delta)}{1-\delta(1-\alpha)}K \tag{3.4}$$

Finally, we can check that $\Delta_1 = \frac{1-\alpha}{1-\delta(1-\alpha)}K > 0$ as promised.

The case of one inefficient incumbent

Consider now the case $x = (K,0)$ and $c^E < c^I$. By switching the roles of the entrant and the incumbent, we already know from the analysis of the previous case that

$$\begin{aligned} \pi^I(0,K) &= 0 && (3.5) \\ \pi^E(0,K) &= \frac{1-\alpha}{1-\delta}(c^I - c^E) + \frac{1-\alpha}{1-\delta(1-\alpha)}K && (3.6) \end{aligned}$$

It only remains to find out what happens when the current incumbent (i.e., the firms that is currently the only owner of the asset) is the less efficient firm. In the present case, this means finding $\pi^I(K,0)$ and $\pi^E(K,0)$. By symmetry, we will then find $\pi^I(0,K)$ and $\pi^E(0,K)$ for the case $c^I < c^E$.

If the entrant wins, efficient subcontracting requires the sale of the asset and we have

$$\begin{aligned}
Dis &= \{0 + \delta\pi^I(K,K); s - c^E - K + \delta\pi^E(K,K)\} \\
Eff &= \{p_K + \delta\pi^I(0,K); s - p_K - c^E + \delta\pi^E(0,K)\} \\
GT &= K + \delta[\pi^I(0,K) + \pi^E(0,K) - \pi^I(K,K) - \pi^E(K,K)] \\
&= K + \frac{\delta(1-\alpha)}{1-\delta(1-\alpha)}K > 0
\end{aligned}$$

The gains from trade are positive, so the asset is sold. The asset price and the firms' profits are

$$\begin{aligned}
p_K &= \frac{1-\alpha}{1-\delta(1-\alpha)}K \\
\pi_L^I(s) &= p_K \\
\pi_W^E(s) &= s - p_K - c^E + \delta\pi^E(0,K)
\end{aligned}$$

If the incumbent wins, efficient subcontracting requires that the incumbent delegates production to the entrant to whom it transfers the asset. We obtain

$$\begin{aligned}
Dis &= \{s - c^I + \delta\pi^I(K,0); 0 + \delta\pi^E(K,0)\} \\
Eff &= \{s - p_{KS} + \delta\pi^I(0,K); p_{KS} - c^E + \delta\pi^E(0,K)\} \\
GT &= c^I - c^E + \delta[\pi^I(0,K) + \pi^E(0,K) - \pi^I(K,0) - \pi^E(K,0)]
\end{aligned}$$

As in the previous case, assume for the moment (and prove later) that $\Delta_2 \equiv \pi^I(0,K) + \pi^E(0,K) - \pi^I(K,0) - \pi^E(K,0) \geq 0$. The gains from trade are thus positive and the transaction will occur at price

$$p_{KS} = \alpha c^E + (1-\alpha)c^I - \delta[\pi^E(0,K) - \pi^E(K,0)] + (1-\alpha)\delta\Delta_2$$

leading to firms' profits of

$$\begin{aligned}\pi^I_W(s) &= s - p_{KS} \\ \pi^E_L(s) &= (1-\alpha)(c^I - c^E) + \delta\pi^E(K,0) + (1-\alpha)\delta\Delta_2\end{aligned}$$

The firms' bids will thus be

$$\begin{aligned}b^I &= \pi^I_L(s) - \pi^I_W(s) + s \\ &= \alpha c^E + (1-\alpha)c^I + \frac{1-\alpha}{1-\delta(1-\alpha)}K + \\ &\quad -\delta[\pi^E(0,K) - \pi^E(K,0)] + (1-\alpha)\delta\Delta_2 \\ &= \pi^E_L(s) - \pi^E_W(s) + s \\ &= b^E = s\end{aligned}$$

It follows that

$$\pi^I(K,0) = \frac{1-\alpha}{1-\delta(1-\alpha)}K \tag{3.7}$$

and that $\pi^E(K,0)$ must solve the following equation

$$\pi^E(K,0) = (1-\alpha)(c^I - c^E) + \delta\pi^E(K,0) + (1-\alpha)\delta\Delta_2$$

Plugging in the expressions for the known $\pi^f(x^I, x^E)$ we get

$$\pi^E(K,0) = \frac{1-\alpha}{1-\delta}(c^I - c^E) \tag{3.8}$$

Thus $\Delta_2 = 0 \geq 0$, as promised.
The level of subsidy is then

$$s(K,0) = \alpha c^E + (1-\alpha)c^I + \frac{(1-\alpha)(1-\delta)}{1-\delta(1-\alpha)}K \tag{3.9}$$

In sum, we have shown that, if at least one of the firms initially owns the asset

$$s(x^I, x^E) = \alpha c^{(1)} + (1-\alpha)c^{(2)} + \frac{(1-\alpha)(1-\delta)}{1-\delta(1-\alpha)}(K - x^{(2)}) \tag{3.10}$$

$$\pi^f(x^I, x^E) = \frac{1-\alpha}{1-\delta}(c^{(2)} - c^f)^+ + \frac{1-\alpha}{1-\delta(1-\alpha)}(x^f - x^{(2)})^+ \tag{3.11}$$

where $c^{(i)}$ is the i^{th} lowest c^f, while $x^{(i)}$ is the i^{th} highest x^f.

The case of unserved consumers

To conclude the analysis of the single-consumer two-firm case, it remains to compute the level of subsidy $s(0,0)$ and profits $\pi^f(0,0)$ when neither firm initially owns the asset. By going through the same kind of analysis, we obtain

$$s(0,0) = \alpha c^{(1)} + (1-\alpha)c^{(2)} + [1 - \frac{\delta(1-\alpha)}{1-\delta(1-\alpha)}]K \tag{3.12}$$

$$\pi^f(0,0) = \frac{1-\alpha}{1-\delta}(c^{(2)} - c^f)^+ \tag{3.13}$$

General case

Summing up, we have that the net present value of all the subsidies paid for a given consumer is

$$s_{Tot} = \begin{cases} \frac{1}{1-\delta}[\alpha c^{(1)} + (1-\alpha)c^{(2)}] + K & \text{if} \quad x = (0,0) \\ \frac{1}{1-\delta}[\alpha c^{(1)} + (1-\alpha)c^{(2)}] & \text{if} \quad x = (K,K) \\ \frac{1}{1-\delta}[\alpha c^{(1)} + (1-\alpha)c^{(2)}] + \frac{1-\alpha}{1-\delta(1-\alpha)}K & \text{otherwise} \end{cases} \tag{3.14}$$

Finally, we can generalize to the case of arbitrarily many firms and consumer classes:

Proposition 9 *Consider a sequence of full-information COLR auctions with SRF-bargaining over assets and production and no reserve prices. If firms' costs are additive across consumer classes and assets are fully transferable and infinitely lived, in all Markov-perfect equilibria the Universal Service obligation would be satisfied at a total discounted cost of*

$$s_{Tot} = \sum_{h \in H} q_h \frac{1}{1-\delta}[\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)}] +$$

$$+ \sum_{\{h|\forall f, x_h^f = 0\}} q_h K_h + \sum_{\{h|\exists f, x_h^f = K_h\}} q_h \frac{1-\alpha}{1-\delta(1-\alpha)}(K_h - x_h^{(2)})$$

The firms' total discounted profit would be

$$\pi^f = \frac{1-\alpha}{1-\delta} \sum_h q_h (c_h^{(2)} - c_h^f)^+ + \frac{1-\alpha}{1-\delta(1-\alpha)} \sum_h q_h (x_h^{(f)} - x_h^{(2)})^+ \tag{3.15}$$

Proof (sketch): As in the special case $\delta = K_h = 0$ studied in Chapter 2, it can be shown that subsidies and profits are additive in the set of consumers. Therefore, the proposition is true when there are only two firms and an arbitrary number of consumer classes.

When there are three or more firms, two complications are introduced. First, in addition to direct subcontracting, the obligation to serve may now be transferred via auctions. Second, subcontracting service to consumer h may now require bargaining with two different firms: the owner of K_h and η_h, the firm with the lowest per-period cost to serve h.

The machinery of proof used in Chapter 2 relied on the ease with which one could identify the (negative) value of the obligation to serve for each firm. This is not so easy in the present context.[13]

The easiest way to prove the result is to use the "guess-and-verify" method. I will omit the tedious computational detail and simply sketch the proof.

Assume that the profit (value) function in the text of the proposition is the right one. Then the changes in profits associated with changes in asset ownership structure are independent of $\{c_h^f\}_{h \in H}^{f \in F}$. The winner of the COLR auction can be thought of as running two separate processes, one for procuring K_h (if it does not yet own it) and another for trading it to η_h in exchange for the provision of service to h plus a monetary balance which could be of either sign. It is actually simpler to think in terms of asset leases: the COLR only leases the asset for one period to η_h and pays η_h for the provision of service.[14] Following the usual logic, the opportunity cost of

[13] Already in the two-firms analysis above, we had to solve a system of equations for the values $\pi^f(x^I, x^E)$ distinguishing whether the incumbent was more or less efficient than the entrant.

[14] Equivalently, it sells K_h to η_h and then buys it back before the next auction.

the obligation to serve h is equal to $\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)}$ plus the rental cost of K_h. The latter is zero if there are duplicate facilities. If only one firm owns K_h, then its rental value is determined as follows. If there is disagreement between the COLR and the incumbent, the COLR will have to procure K_h externally. This would cost the incumbent all the future profits from owning K_h. Since these can be computed from the assumed form of the value function, the gains from trade with respect to K_h are

$$GT = K_h + \delta \frac{1-\alpha}{1-\delta(1-\alpha)} K_h$$

and the rental value r_h of K_h is the solution to the following equation

$$r_h + \delta \frac{1-\alpha}{1-\delta(1-\alpha)} K_h = (1-\alpha) GT$$

which, as required, is

$$r_h = \frac{(1-\alpha)(1-\delta)}{1-\delta(1-\alpha)} K_h$$

The proof for the case of unserved consumer classes is similar.

Q. E. D.

Remark: If the assets K_h are not a "per consumer" cost, but a "per consumer class" cost, the analysis is practically unchanged. The only change in the final formulas is that q_h should be dropped from the asset cost components. Therefore the analysis can accommodate economies of scope to a limited extent.

Remark: It is straightforward to further generalize the above proposition to the case in which variable costs change from period to period, provided that their probability distribution does not depend on asset ownership.

Remark: Since $\frac{1-\alpha}{1-\delta(1-\alpha)} \in [0, \infty)$, an incumbent can recover more or less than its initial investments.[15] However, the incumbents' initial investments will surely be (partially) "stranded" if $\alpha \geq 0.5$, i.e., if the winner of the auction has at least as much bargaining power as the losers. Since the "stranded costs" issue is common to COLR

[15] Note that this statement (but not the following one) is true even if the cost of the asset was not equal to K_h at the time the incumbent incurred it.

auctions and EPOS schemes, I will not discuss its legal and economic aspects.[16]

3.2.2 Firm-specific sunk assets

Assume now that the assets K_h are not transferable, but fully sunk. Even if the assets are not transferable, it may still be possible to subcontract the provision of service and I assume so in the following. The analysis of this case is analogous to the one in which the assets are assumed to be transferable without loss. The presence of sunk costs, however, introduces a new possibility: production by the entrant may be unprofitable for bidders even when it is efficient. The intuition is easily described: if the incumbent has relatively high variable costs, delegating production to an entrant may be efficient even considering the necessity to build duplicate assets, but the presence of duplicate assets may reduce the equilibrium level of subsidies in future auctions by more than the cost savings.[17]

For simplicity, I only consider a model with one consumer (class), one incumbent and one entrant.[18] Thus the system can be in only two states: $x = (K, 0)$ or $x = (K, K)$. To save on notation, I will drop the first component of the state and write $x \in \{0, K\}$.[19]

First note that, as in the case of transferable assets, $x = K$ is an absorbing state and the (stationary) equilibrium is the one computed in the previous chapter. We can thus focus on state $x = 0$.

If $c^I < c^E$, the fact that assets are not transferable is irrelevant. In this case, efficient subcontracting means delegating production to the incumbent and this does not require building duplicate assets that would lower future subsidies. Formally, the equilibrium computations of the previous section go through unchanged.

The trade-off between cost savings and lower future subsidies occurs when $c^I > c^E$. In this case, efficiency requires that duplicate assets be built if and only if $c^I - c^E >$

[16] See Sidak and Spulber (1999) for a book-length treatment.

[17] With transferable assets subcontracting can always occur without building duplicate assets and thus leaving future subsidies unaffected.

[18] By now it should be clear how to extend the results to cover more general cases.

[19] The reader uninterested in going through the usual laborious equilibrium computations can skip to the end of this section, where the final results are summarized.

$(1-\delta)K$, i.e., if and only if the net present value of cost savings from delegating production to the entrant in all periods are larger than the cost of duplicating the assets. Instead, as shown below, the equilibrium outcome implements a different (more stringent) test.

If the incumbent wins the auction and there is no subcontracting, payoffs are

$$Dis = \{s - c^I + \delta\pi^I(0); \delta\pi^E(0)\}$$

If production is delegated to the entrant (who will have to build duplicate assets for the purpose) and the subcontracting price is p_S, payoffs are

$$\begin{aligned} Sub &= \{s - p_S + \delta\pi^I(K); p_S - c^E - K + \delta\pi^E(K)\} \\ &= \{s - p_S; p_S - c^E - K + \delta\frac{1-\alpha}{1-\delta}(c^I - c^E)\} \end{aligned}$$

Subcontracting will occur only if it increases total payoffs, i.e., if

$$GT = c^I - c^E - K - \delta[\pi^I(0) + \pi^E(0) - \frac{1-\alpha}{1-\delta}(c^I - c^E)] \tag{3.16}$$

is positive. Let us assume so for the moment.[20]

By the usual assumption, the subcontracting price will give the entrant a fraction $1-\alpha$ of the gains from trade and will thus solve the following equation

$$p_S - c^E - K + \delta\frac{1-\alpha}{1-\delta}(c^I - c^E) = \delta\pi^E(0) + (1-\alpha)GT$$

The solution is

$$p_S = \alpha(c^E + K) + (1-\alpha)c^I - \alpha\delta\frac{1-\alpha}{1-\delta}(c^I - c^E) + \alpha\delta\pi^E(0) - (1-\alpha)\delta\pi^I(0)$$

If the entrant wins, the gains from trade are negative[21] and there is no subcontracting. The entrant will build duplicate assets and provide the service, leading to

[20] The condition for this assumption to be consistent are derived below.

[21] They are equal to minus GT in equation 3.16 and we are temporarily assuming $GT > 0$.

payoffs equal to

$$\{0; s - c^E - K + \delta\frac{1-\alpha}{1-\delta}(c^I - c^E)\}$$

The usual calculations show that

$$b^E = p_S = b^I = s$$

and that firms' profits are thus equal to

$$\begin{aligned}\pi^I(0) &= 0\\ \pi^E(0) &= \frac{1-\alpha}{1-\delta}[c^I - c^E - \frac{1-\delta}{1-\alpha\delta}K]\end{aligned}$$

Since firms can simply refuse to participate in the auction, the entrant's profit must be positive. The preceding calculations thus identify an equilibrium only if

$$c^I - c^E - \frac{1-\delta}{1-\alpha\delta}K \tag{3.17}$$

is positive.[22] If so, the gains from trade can be shown to be exactly equal to (3.17), hence they are positive and production will be delegated to the entrant - which is the efficient outcome since $c^E + \frac{1-\delta}{1-\alpha\delta}K < c^I$ implies $c^E + (1-\delta)K < c^I$.

The equilibrium level of subsidies is then

$$s(0) = p_S = \alpha(c^E + \frac{1-\delta}{1-\alpha\delta}K) + (1-\alpha)c^I \tag{3.18}$$

in the first period and

$$s(K) = \alpha c^E + (1-\alpha)c^I \tag{3.19}$$

forever after.

We have seen that, if (3.17) is negative, there is no (Markov) equilibrium in which (3.16) is positive.

It only remains to consider the case in which (3.16) is negative, i.e., when the sum

[22]Note also that $\frac{1-\alpha}{1-\delta}[c^I - c^E - \frac{1-\delta}{1-\alpha\delta}K] > \frac{1-\alpha}{1-\delta}(c^I - c^E) - K = \pi^E(K) - K$ so the entrant has no incentive to build duplicate assets before the auction.

of the firms' payoffs would be lowered by duplicating the assets. As shown below, this will occur in equilibrium only if (3.17) is also negative, so the analysis is complete.

So let us assume that (3.16) is negative and go through the usual calculations. When the incumbent wins there is no subcontracting and payoffs are

$$\{s - c^I + \delta\pi^I(0); \delta\pi^E(0)\}$$

When the entrant wins, the gains from subcontracting are equal to minus GT, hence positive, and production is delegated to the incumbent at price

$$p_S = c^I - \delta\pi^I(0) - (1-\alpha)GT$$

The corresponding payoffs are

$$\{p_S - c^I + \delta\pi^I(0); s - p_S + \delta\pi^E(0)\}$$

We would then get $b^I = b^E = s = p_S$ and profits would be

$$\begin{aligned} \pi^I(0) &= \frac{(1-\alpha)(1-\alpha\delta)}{(1-\delta)[1-(1-\alpha)\delta]}[\frac{1-\delta}{1-\alpha\delta}K - (c^I - c^E)] \\ \pi^E(0) &= 0 \end{aligned}$$

Note that $\pi^I(0) > 0$ requires that (3.17) be negative. Note also that the entrant cannot get positive payoffs from building duplicate assets and moving to $x = K$ because, as shown above, $\pi^E(K) - K = \frac{1-\alpha}{1-\delta}(c^I - c^E) - K < \frac{1-\alpha}{1-\delta}[c^I - c^E - \frac{1-\delta}{1-\alpha\delta}K]$ and this is negative whenever (3.17) is negative.

Under this condition, we can also verify that actually $GT < 0$, as assumed above.[23]

The equilibrium level of subsidy can be computed by plugging these values back

[23]For the record,

$$GT = \frac{1-\alpha\delta}{(1-\delta)[1-(1-\alpha)\delta]}[c^I - c^E - \frac{1-\delta}{1-\alpha\delta}K]$$

into the formula for p_S and we get

$$s = c^I + \frac{(1-\alpha)(1-\alpha\delta)}{1-(1-\alpha)\delta}[\frac{1-\delta}{1-\alpha\delta}K - (c^I - c^E)] \tag{3.20}$$

We can finally summarize the results of this section in the following proposition

Proposition 10 *Consider a sequence of COLR auctions without reserve price for one consumer (class) with one incumbent having per-period costs equal to c^I and an entrant having per-period costs equal to c^E. Assume that the entrant would also have to incur a sunk cost K before it can provide any service. Let δ be the common discount factor and α be the share of the gains from subcontracting received by auction winners. Let all this information be common knowledge for the firms.*

Then, in all Markov-perfect equilibria, service will be provided by the incumbent if

$$c^I - c^E < \frac{1-\delta}{1-\alpha\delta}K$$

Otherwise, service will be provided by the entrant.

As a consequence, entry is efficient when it occurs, but it fails to occur even if it would be efficient when

$$(1-\delta)K < c^I - c^E < \frac{1-\delta}{1-\alpha\delta}K$$

The firms' profits, the level of subsidies in the initial period and the net present value of total subsidies are reported in the tables below.

$c^I - c^E$	$\pi^I(0)$	$\pi^E(0)$
$c^I - c^E < 0$	$\frac{1-\alpha}{1-\delta}(c^I - c^E) + \frac{1-\alpha}{1-\delta(1-\alpha)}K$	0
$0 < c^I - c^E < \frac{1-\delta}{1-\alpha\delta}K$	$\frac{1-\alpha}{1-\delta}\frac{1-\alpha\delta}{1-\delta(1-\alpha)}[\frac{1-\delta}{1-\alpha\delta}K - (c^I - c^E)]$	0
$\frac{1-\delta}{1-\alpha\delta}K < c^I - c^E$	0	$\frac{1-\alpha}{1-\delta}(c^I - c^E - \frac{1-\delta}{1-\alpha\delta}K)$

$c^I - c^E$	$s(0)$	s^{Tot}
$c^I - c^E < 0$	$\alpha c^I + (1-\alpha)c^E + \frac{(1-\delta)(1-\alpha)}{1-\delta(1-\alpha)}K$	$\frac{\alpha c^I + (1-\alpha)c^E}{1-\delta} + \frac{1-\alpha}{1-\delta(1-\alpha)}K$
$0 < c^I - c^E < \frac{1-\delta}{1-\alpha\delta}K$	$c^I + \frac{(1-\alpha)(1-\alpha\delta)}{1-\delta(1-\alpha)}[\frac{1-\delta}{1-\alpha\delta}K - (c^I - c^E)]$	$\frac{1}{1-\delta}s(0)$
$\frac{1-\delta}{1-\alpha\delta}K < c^I - c^E$	$\alpha c^E + (1-\alpha)c^I + \alpha\frac{1-\delta}{1-\alpha\delta}K$	$\frac{\alpha c^E + (1-\alpha)c^I}{1-\delta} + \frac{\alpha(1-\delta)}{1-\alpha\delta}K$

Remark: Note that the incumbent may have never paid the entry cost K. It may be simply a firm that uses a technology with low (zero) sunk costs. The results in this section then suggest that COLR auctions are biased against technologies that have higher sunk costs. It seems reasonable to expect the same of EPOS schemes, at least if subcontracting is relevant for them as well.[24]

3.2.3 Unbundling obligations

The Telecommunications Act of 1996 mandates, *inter alia*, that incumbent Local Exchange Carrier (ILEC) provide access to their "unbundled network elements" (UNE) at regulated prices to all other carriers.[25] I am not going to discuss here the rationale and the implications of this policy in general, but I simply derive the corresponding equilibrium level of subsidies in a COLR auction. In particular, I will show that *the imposition of the UNE obligation may actually benefit the incumbent.*

The intuition for this result is that the possibility for the entrant to lease the asset at (sufficiently low) regulated prices destroys the credibility of a winning entrant's threat to build duplicate facilities. For some range of UNE regulated prices, this would make the disagreement outcome in the subcontracting negotiations more favorable to the incumbent and lead to higher equilibrium rental prices (hence higher subsidies and profits) than in the absence of unbundling obligations.

For notational simplicity, let us assume that $c_h^f = 0$ for all f and h and that there is only one consumer, one incumbent ($x^I = K$) and one entrant ($x^E = 0$). Let $\bar{p}_K$ be the regulated UNE price. It is obvious that the UNE obligation is irrelevant if $\bar{p}_K \geq K$, so let's assume $\bar{p}_K < K$. It is also clear that subsidies and profits are equal to zero when both firms have the asset ($x = (K, K)$). Now consider what happens when $x = (K, 0)$ and the entrant wins the auction. The efficient outcome is, as before, for the entrant to lease (or buy) the incumbent's asset. The disagreement outcome now depends on the equilibrium payoffs: if $-\bar{p}_K + \delta V^E(K, 0) > -K + \delta V^E(K, K)$, then the entrant will use its legal right to lease K at price $\bar{p}_K$; otherwise, it will build duplicate facilities.

[24]See section 3.2.4.

[25]See Section 251 of the Act.

However, as shown below (and as intuitively obvious), $V^E(K,0) = V^E(K,K) = 0$ in equilibrium, so the latter case cannot happen.

In fact, assume (*ad absurdum*) that $-\bar{p}_K + \delta V^E(K,0) < -K + \delta V^E(K,K)$, so that the disagreement payoffs are

$$Dis = \{0 + \delta V^I(K,K); s - K + \delta V^E(K,K)\} = \{0, -K\}$$

The payoffs in the efficient outcome (i.e., leasing the asset at some rental rate r_K) are

$$Eff = \{r_K + \delta V^I(K,0); s - r_K + \delta V^E(K,0)\}$$

The gains from trade would be

$$GT = K + \delta[V^I(K,0) + V^E(K,0)]$$

and the rental price would be

$$r_K = \bar{p}_K \wedge [-\delta V^I(K,0) + (1-\alpha)GT]$$

If the incumbent wins the COLR auction instead, there is no subcontracting and the payoffs are $\{s + \delta V^I(K,0); 0 + \delta V^E(K,0)\}$.

As usual, the equilibrium level of bids (and subsidy) leaves bidders indifferent between winning and losing, so the entrant's equilibrium payoff is

$$V^E(K,0) = \delta V^E(K,0) = 0$$

which implies

$$-\bar{p}_K + \delta V^E(K,0) = -\bar{p}_K > -K = -K + \delta V^E(K,K)$$

contradicting the initial assumption.

We have thus shown that $-\bar{p}_K + \delta V^E(K,0) > -K + \delta V^E(K,K)$. Therefore, the disagreement payoffs when the entrant wins the COLR auction will be

$$Dis = \{\bar{p}_K + \delta V^I(K, 0); s - \bar{p}_K + \delta V^E(K, 0)\}$$

and the disagreement outcome will also be efficient.

The usual calculations show that, if $\bar{p}_K < K$, the Markov-perfect outcome with zero variable cost is

$$\begin{aligned} s &= \bar{p}_K \\ V^I(K, 0) &= \frac{1}{1-\delta}\bar{p}_K \\ V^E(K, 0) &= 0 \end{aligned}$$

If instead $\bar{p}_K > K$ and, in particular, if the obligation is not imposed (i.e., $\bar{p}_K = \infty$), the previous analysis in this chapter shows that the outcome would be

$$\begin{aligned} s &= b^I = b^E = \frac{1-\alpha}{1-\delta(1-\alpha)}K \\ V^I(K, 0) &= \frac{(1-\delta)(1-\alpha)}{1-\delta(1-\alpha)}K \\ V^E(K, 0) &= 0 \end{aligned}$$

As mentioned above, we thus obtain the following remarkable result:

Proposition 11 *The imposition of an "unbundling" obligation increases the incumbent's profits if and only if*

$$\frac{1-\alpha}{1-\delta(1-\alpha)}K < \bar{p}_K < K$$

In particular, if $\bar{p}_K = (1-\delta)K$, the unbundling obligation benefits the incumbent if and only if $\frac{\alpha}{1-\alpha} > \delta$. Note that this is precisely the same condition under which, absent the unbundling obligation, the incumbent's asset would be (partially) "stranded." Setting $\bar{p}_K = (1-\delta)K$, and assuming that K also represents the original cost of the asset for the incumbent, would eliminate the "stranded cost" issue.

3.2.4 EPOS schemes

The definition of the optimal EPOS scheme in a dynamic context is quite problematic. First, it is unclear whether the minimum subsidy should be taken as fixed once and for all (at least bar technological changes) or adapted to changes in the profile of asset ownership. Second, even if the subsidy level is kept constant, its minimum level will depend on the precise timing and structure of the market for the subsidized service and the subcontracting market. For example, given any (sufficiently high) level of subsidy s, it is unclear what the outcome of competition for a consumer (class) h would be if the incumbent has higher variable costs, but lower overall costs than the most efficient entrant (i.e., if $c_h^{\eta(h)} < c_h^{I_h} < c_h^{\eta(h)} + (1-\delta)K_h$ when $x_h^{\eta(h)} = 0$.)

The spirit of the results derived in Chapter 2, however, seems robust to all reasonable specifications: the subsidy paid by the optimal EPOS scheme will depend on the "marginal" consumer class, that is by the consumer class that is most expensive to serve; the subsidy under a COLR auction is instead an average of those costs.

Possibly the most favorable scenario for EPOS schemes is to allow firms to sign binding long-term contracts with consumers and then engage in (efficient) subcontracting.[26] In this case, we can assume that, if assets are transferable, the asset ownership will not change except for temporary (intra-period) leases, so the per period subsidy will be constant. By the same logic used in the analysis of COLR auctions with subcontracting, the (per period) opportunity cost of serving a consumer of class h would be $\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)} + (1-\delta)(1-\alpha)K_h$ for both the incumbent I_h and all other firms. If there is an incumbent for any consumer, but no duplicate facilities, the optimal EPOS would then be

$$\underline{s}^{EPOS} = \max_h \{\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)} + (1-\delta)(1-\alpha)K_h\}$$

In the corresponding case, the subsidy under a COLR auction would be

$$s^{COLR} = \sum_{h\in H} q_h[\alpha c_h^{(1)} + (1-\alpha)c_h^{(2)} + \frac{(1-\delta)(1-\alpha)}{1-\delta(1-\alpha)}K_h]$$

[26] Note that, unlike the case studied in Chapter 2, the (productive) efficiency of EPOS schemes now requires efficient subcontracting unless $c_h^{\eta(h)} = c_h^{I_h}$ for all h.

Remark: The difference in the K_h terms between the two expressions depends on the fact that (potential) changes in asset ownership profiles affect future subsidies under COLR auctions, but (given the current assumptions) not under EPOS schemes.

Remark: If unbundling obligations are imposed and $\bar{p}_{K_h} < K_h$ for all h, then the K_h terms in both expressions would be replaced by $\bar{p}_{K_h}$.

As in the static case studied in Chapter 2, we have that:

- EPOS schemes tend to perform better than COLR auctions when consumers are similar and worse when consumers are heterogeneous.
- COLR auctions always outperform EPOS schemes when α is sufficiently large, i.e., when "buyers" have sufficient bargaining power in subcontracting negotiations.

3.3 Economies of scope

There is no question that Local Exchange Carriers' cost functions are not additive in the set of consumers they serve. Although the extent of economies of scale (in switching and transmission) is unclear,[27] there are obvious economies of scope in distribution: once a firm has decided to serve a consumer, its marginal cost to serve that consumer's neighbors will be considerably reduced. Cost synergies within small geographic areas may be particularly significant for wireless technologies.[28]

Since it is not possible to derive closed form solutions for EPOS schemes and COLR auctions with subcontracting in the case of general sub-additive cost functions, I only consider the case in which there is a fixed cost to serve the area in addition to the marginal per-subscriber costs as in Chapter 2. I show that, even in this special case, it is not possible to state in general which subsidization scheme has a comparative advantage in coping with cost synergies.

[27] See Shin and Ying (1992).

[28] Ausubel *et al.* use bidding data from PCS spectrum auctions to estimate synergies at the level of BTAs and MTAs. They find that, even at this relatively high level of aggregation, there were small but significant synergies.

I maintain the notation and assumptions of Chapter 2, except that any firm f that serves some consumers in the area must now incur a fixed cost equal to d^f. To make comparisons easier, I assume that unit costs are reduced by the same amount, so that each firm's cost of serving the whole area remains unchanged: $d^f + \sum_h q_h(c_h^f - d^f) = d^f - d^f \sum_h q_h + \sum_h q_h c_h^f = d^f - d^f + \sum_h q_h c_h^f = \sum_h q_h c_h^f$.

Clearly, this change does not affect COLR auctions when subcontracting is not feasible.

It can be shown, however, that

Lemma 1 *The shift from variable to fixed costs cannot decrease the minimum total production costs. Minimum total costs remain unchanged only if the area is a natural monopoly both before and after the change.*

Proof:

The minimum total cost of serving the area when $d^f = 0$ for all f is $\sum_{h \in H} q_h c_h^{(1)}$. Let the optimal market structure with fixed costs be such that consumer class $h \in H$ is served by firm $\phi(h)$. The new minimum total cost is

$$
\begin{aligned}
C_{min} &= \sum_{f \in \phi(H)} [d^f + \sum_{h \in \phi^{-1}(f)} q_h(c_h^f - d^f)] \\
&\geq \sum_{f \in \phi(H)} \sum_{h \in \phi^{-1}(f)} q_h c_h^f \\
&= \sum_{h \in H} q_h c_h^{\phi(h)} \\
&\geq \sum_{h \in H} q_h c_h^{(1)}
\end{aligned}
$$

where the inequalities are strict unless the area would be a natural monopoly even without fixed costs.

Q. E. D.

This suggests that the change should cause EPOS schemes (and, in the case of efficient subcontracting, COLR auctions) to pay higher subsidies. This is true for COLR auctions with efficient subcontracting and no reserve prices.[29] It is not always

[29] Actually, it might be false if the technological change somehow shifted bargaining power in favor of the COLR. But there is no obvious reason why that should happen.

so for the minimal EPOS. In the next section I show that, when the change in technology is substantial (i.e., the d^f terms are large), the minimal EPOS may actually decrease.[30] It should be noted, however, that a COLR auction with a suitable reserve price would then do just as well.

3.3.1 High fixed costs

Assume that the fixed cost component is sufficiently high that $c_h^f - d^f < \bar{p}$ for all f and h.[31] So, once a firm has entered the area and spent the fixed cost, it would profit from being the only firm in the market and serving every consumer. Still, the area remains high-cost: no firm will enter by itself without a subsidy unless it can charge above $\bar{p}$;[32] the following lemma guarantees that no other collection of firms would do it either.

To save on notation, let us order firms in terms of increasing average costs, i.e., $\sum_h c_h^f q_h < \sum_h c_h^g q_h$ if and only if $f < g$.

Lemma 2 *If $c_h^f - d^f < \bar{p}$ for all f and h, then the area is a natural monopoly.*

Proof:

By definition, firm 1 would be the most efficient monopolist. We need to show that no collection of firms could serve the whole area at lower cost. Consider an arbitrary pair of firms f and g and market division F and G ($F \cap G = \emptyset$, $F \cup G = H$, where H is the set of consumer classes). Their total costs would be

$$\begin{aligned} & d^f + \sum_{h \in F} (c_h^f - d^f) q_h + d^g + \sum_{h \in G} (c_h^g - d^g) q_h \\ = \; & d^f + \sum_{h \in F} (c_h^f - d^f - \bar{p}) q_h + d^g + \sum_{h \in G} (c_h^g - d^g - \bar{p}) q_h + \bar{p} \end{aligned}$$

[30] I also provide an example in which the optimal EPOS increases.

[31] This requires $\bar{p} > \max_h c_h^f - \min_h c_h^f$ for all h if marginal cost is to be positive for each consumer class.

[32] By assumption $c_h^f > \bar{p}$ for all f and h, so $\bar{p} < \sum_h q_h c_h^f = d^f + \sum_h q_h (c_h^f - d^f)$.

Since $c_h^i - d^i - \bar{p} < 0$ for all i and h, this is greater than

$$\begin{aligned} & d^f + \sum_{h \in H} (c_h^f - d^f - \bar{p}) q_h + d^g + \sum_{h \in H} (c_h^g - d^g - \bar{p}) q_h + \bar{p} \\ = \; & \sum_{h \in H} c_h^f q_h + \sum_{h \in H} c_h^g q_h + \bar{p} \\ > \; & 2 \sum_{h \in H} c_h^1 q_h + \bar{p} \\ > \; & \sum_{h \in H} c_h^1 q_h \end{aligned}$$

Similarly one can show that any market structure in which $n > 2$ firms are active is less efficient than the most efficient monopolist.

Q. E. D.

Proposition 12 *The optimal EPOS is*

$$\underline{s}^{EPOS} = [(\sum_h c_h^1 q_h) \vee v \wedge (\sum_h c_h^2 q_h)] - \bar{p}. \tag{3.21}$$

The (subgame-perfect) equilibrium level of subsidy in a COLR auction with SRF subcontracting is

$$s^{COLR} = \alpha \sum_h c_h^1 q_h + (1 - \alpha) \sum_h c_h^2 q_h - \bar{p}. \tag{3.22}$$

Proof:

If $s < (v \wedge \sum_h c_h^2 q_h) - \bar{p}$, then firm 1 would rather set a price equal to $(v \wedge \sum_h c_h^2 q_h) - \epsilon$ for arbitrarily small ϵ than take the subsidy s and price at $\bar{p}$ - for it would serve the whole area anyway and get higher revenues. Provided it covers firm 1's costs, a subsidy $s = (v \wedge \sum_h c_h^2 q_h) - \bar{p}$ is sufficient because competition from firm 2 and/or lack of demand prevent firm 1 from getting higher revenues. This establishes the first part of the proposition.

The second part follows from the fact that firm 2 can bargain directly with firm 1 after the auction and get a subcontracting price of $\alpha \sum_h c_h^1 q_h + (1 - \alpha) \sum_h c_h^2 q_h$. The proof of the lemma above can be used to show that $\sum_h c_h^2 q_h$ is the minimum cost to serve the area without firm 1, so no collection of firms bargaining collectively against firm 1 could do any better than firm 2 alone.

Q. E. D.

Remark: If demand is sufficiently low then the optimal EPOS is better than a COLR auction without reserve prices. But a COLR auction with reserve price equal to $\underline{s}^{EPOS}$ does always at least as well as the optimal EPOS scheme - regardless of the efficiency and structure of subcontracting.

3.3.2 Low fixed costs

If fixed costs are sufficiently low, then they may increase the optimal EPOS and make it worse than a COLR auction without subcontracting or reserve prices. To show this, let us start with a situation in which the two schemes have the same cost in the absence of fixed costs: $\max_h \min_f c_h^f = \sum_h c_h^2 q_h$.

Consider the case in which $c_h^f - d^f > \bar{p}$ for all f and h – so that all consumers remain "high-cost" even after all firms have paid their fixed costs.[33] Let k be the consumer class with the highest marginal cost in the efficient market structure and g the firm that would serve k in the efficient market structure. Assume that, in the efficient market structure, firm g only serves consumer class k. Let

$$\tilde{s} = c_k^g + \frac{1 - q_k}{q_k} d^g - \bar{p}$$

so that firm g would make zero profits by serving k only.

Note that $\tilde{s}$ is larger than the optimal EPOS with no fixed costs.[34] It remains to show that no other firm would be willing to serve k at this level of subsidy. First consider a firm f that is active in the efficient market structure. Since (by definition) g serves k in the efficient market structure, it must be the case that

$$(c_k^f - d^f) > (c_k^g - d^g) + \frac{1}{q_k} d^g$$

[33] Less restrictive conditions would suffice.

[34] The assumption that g only serves k was made precisely to guarantee this. Clearly, it is only a sufficient condition, not a necessary one.

which is equivalent to

$$c_k^f - d^f > \bar{p} + \tilde{s}$$

so firm f would not serve k. Clearly, no firm that would not be active in the efficient market structure could be willing to serve k with subsidy $\tilde{s}$ because firm g is (by definition) more efficient at doing so and yet earns no profit.

Summing up, we have shown that a small shift from variable to fixed costs may increase the optimal EPOS and make it higher than the equilibrium level of subsidies in a COLR auction without subcontracting. Interestingly, the example focuses on the presence of a niche carrier: firm g must not be good for much else than serving consumer class k. Thus it goes counter the intuition (valid in the pure variable costs case) that EPOS schemes are particularly suited to exploit the presence of niche carriers.

3.4 Incomplete information

All the preceding models (and those following this section) incorporate the assumption of common knowledge among bidders. The main rationale for that assumption is to avoid the complications that would follow from deriving the equilibria of trading games (the market equilibria under EPOS schemes and the subcontracting trades under COLR auctions) with asymmetric information. In the case of COLR auctions, there would be an added layer of complexity due to the informational linkages between the auction and the subcontracting stages: a firm may find it profitable to alter its bids in order to affect other firms' beliefs about its true costs and obtain larger gains in the subcontracting stage.[35]

These complexities, however, can be avoided without requiring common knowledge among bidders at the auction stage. It is enough to assume that bidders learn each

[35] Ausubel and Cramton (1999) show that this will not happen with (generalized) Vickrey auctions. In a single object model, Haile (1998) studies how this kind of strategic considerations affect the expected revenues to the seller depending on the format of the auctions used by the seller and by the "reseller", i.e., the winner of the seller's auction.

other's type after the auction, but before the subcontracting stage.[36] The rest of this section adopts this assumption in a simple two-bidders, two-consumer classes model and shows that, *mutatis mutandis*, the results of Chapter 2 remain valid.

3.4.1 Model set-up

There are two firms (Left and Right), and two markets (West and East). Each market has a continuum of consumers with unit total mass. Each consumer demands one unit of the (homogeneous) service offered by the firms. For simplicity, I assume that total demand does not depend on price. Firms compete (Bertrand-like) on prices and they can set different prices in the two markets.

I will refer to the Western market as being the Left's market segment, while the Eastern market will be referred to as the Right's market segment. A firm's cost of serving a consumer in its own market segment is commonly known (by the firms) to be $\gamma > 0$. The firms' (constant) marginal costs of serving consumers in the opponent's market segment are private information and, *ex-ante*, they are commonly believed to be distributed identically and independently according to a distribution $F(c)$ with differentiable density $f(c) > 0$ on its support $[\underline{c}, \overline{c}]$.[37]

The regulator wants service to provided in the area at no more than the "affordable price" $\bar{p}$.

I will maintain the "high-cost area" assumption and, to make things interesting, add the assumption that neither market segment is safe from competition:

$$\bar{p} < \underline{c} < \gamma < \overline{c}$$

Without further loss of generality, we can set $\bar{p} = 0$.

As mentioned above, I will assume that, after the auction, the firms learn each

[36] After writing this section, I learned of related unpublished work by Gupta and Lebrun (1998) who use a set-up similar to the one presented here. They consider an auction for a single indivisible good, but allow bidders to be *ex ante* asymmetric.

[37] An alternative interpretation of the model is that γ is the commonly known cost that a firm incurs in the opponent's market segment, while the costs of serving one's own market segment are private information.

other's information and bargain efficiently (i.e., all gains from trade are realized). The way in which the gains from trade are divided depends on the identity of the firm and, possibly, on whether it has won the auction (i.e., if it is the buyer in the subcontracting stage) or lost it (i.e., if it is the seller in the subcontracting stage): if firm i wins the auction, it will get a fraction $a_i \in (0,1)$ of the gains from trade $(i \in L, R)$.

3.4.2 The subcontracting stage

Let x be Left's cost in the Eastern market and y be Right's cost in the Western market.

Consider first the case in which Left has won the auction. If $\gamma \leq y$, it will serve the Western consumers directly. Otherwise, it will subcontract them to Right and pay $y + (1 - a_L)(\gamma - y) \;=\; a_L y + (1 - a_L)\gamma$.

Similarly, if $x \leq \gamma$, it will serve the Eastern consumers directly and otherwise subcontract them out at a price of $\gamma + (1 - a_L)(x - \gamma) \;=\; a_L\gamma + (1 - a_L)x$. Apart from the subsidy, the firms net revenues will be

$$
\begin{aligned}
v_w^L(x,y) &= -\gamma \wedge (a_L y + (1-a_L)\gamma) - x \wedge (a_L\gamma + (1-a_L)x) \\
&= -\gamma - a_L(y-\gamma)^- - x - a_L(\gamma - x)^- \\
&= -(\gamma + x) + a_L[(\gamma - y)^+ + (x-\gamma)^+] \\
v_l^R(x,y) &= (1-a_L)[(\gamma - y)^+ + (x - \gamma)^+]
\end{aligned}
$$

.

If Right is the winner of the auction, the firms' values will be

$$
\begin{aligned}
v_l^L(x,y) &= (1-a_R)[(y-\gamma)^+ + (\gamma - x)^+] \\
v_w^R(x,y) &= -(\gamma + y) + a_R[(y-\gamma)^+ + (\gamma - x)^+]
\end{aligned}
$$

3.4.3 The auction stage

Consider Left's bidding problem on the assumption that Right is bidding according to a bid function $\beta(y)$, where, at this stage, y is unknown to Left.

Assume now that β is strictly increasing.[38] Left's problem is

$$\max_b \{ \int_{\underline{c}}^{\beta^{-1}(b)} v_l^L(x,y)dF(y) + \int_{\beta^{-1}(b)}^{\overline{c}} [kb + (1-k)\beta(y) + v_w^L(x,y)]dF(y) \} \tag{3.23}$$

where $k = 1$ if the seller uses a first-price auction and $k = 0$ if the seller uses a second-price auction.

The first order condition for this problem is

$$\begin{aligned} 0 \;=\; & (1-a_R)\{[\beta^{-1}(b)-\gamma]^+ + (\gamma - x)^+\}\frac{d\beta^{-1}(b)}{db} f(\beta^{-1}(b)) + \\ & + \int_{\beta^{-1}(b)}^{\overline{c}} k dF(y) + \\ & -(b - x - \gamma + a_L\{[\gamma - \beta^{-1}(b)]^+ + (x-\gamma)^+\})\frac{d\beta^{-1}(b)}{db} f(\beta^{-1}(b)) \end{aligned} \tag{3.24}$$

The sub-differential of [3.24] with respect to x is positive:

$$\begin{aligned} & [1 + (1-a_R)\partial_x(\gamma - x)^+ - a_L)\partial_x(x-\gamma)^+]\frac{d\beta^{-1}(b)}{db} f(\beta^{-1}(b)) \geq \\ & \geq [a_R \wedge (1-a_L)]\frac{d\beta^{-1}(b)}{db} f(\beta^{-1}(b)) > 0 \end{aligned}$$

This guarantees that the best-response to an increasing bidding function is itself increasing.[39] The focus on symmetric equilibria in increasing bidding function is thus justified.

Given that the equilibrium bid functions are increasing (and the assumption of symmetry), the winner of the auction does not depend on k. Therefore the expected

[38] It will be shown later that there is a symmetric equilibrium in increasing strategies.

[39] The profit function, given the opponent's increasing bidding function, is supermodular in (b, x), therefore $b(x)$ is an increasing function.

payoff of the highest possible type ($c_i = \overline{c}$) is also independent of k.[40] However, we cannot apply the revenue equivalence theorem directly. Although the firms' signals are assumed to be independent, the possibility of subcontracting makes their valuations dependent on each other's type.

In the following I derive closed form solution for the second price auction in two polar cases: the case in which bargaining power is completely unaffected by victory in the auction ($a_L = 1 - a_R$) and the case in which it only depends on victory in the auction ($a_L = a_R = a$). I then show that, in the latter case, a first-price auction is revenue equivalent to a second price auction.[41]

Second-price auction

If $a_L = 1 - a_R$, the first-order conditions for the two players become

$$\beta_L(x) = x + \gamma + a_L[\beta_R^{-1} \circ \beta_L(x) - x] \tag{3.25}$$

$$\beta_R(y) = y + \gamma + (1 - a_L)[\beta_L^{-1} \circ \beta_R(y) - y] \tag{3.26}$$

which can be rewritten as

$$\beta_L(c) = \gamma + (1 - a_L)c + a_L\beta_R^{-1}[\beta_L(c)] \tag{3.27}$$

$$\beta_R(c) = \gamma + a_L c + (1 - a_L)\beta_L^{-1}[\beta_R(c)] \tag{3.28}$$

It can be easily seen that one solution of this system is

$$\beta_L(c) = \beta_R(c) = \gamma + c \tag{3.29}$$

[40] Unlike the case of standard auctions, the "worst type" gets a positive payoff in equilibrium:

$$v^{min} = (1 - a_j) \int_{\underline{c}}^{\overline{c}} (c - \gamma)^+ dF(c) = (1 - a_j) Prob(c_i > \gamma)[E(c_i \mid c_i > \gamma) - \gamma] > 0.$$

[41] The assumption that $a_L = a_R = a$ makes bidders completely symmetric. We should not expect revenue equivalence to hold in an asymmetric context - and, in fact, it does not hold in the model by Gupta and Lebrun (1998) cited above.

In this case, *bidding is unaffected by the possibility of resale.*[42] Note that we have found a symmetric equilibrium (indeed, the unique symmetric equilibrium) even though the players are not symmetric (a_L is not necessarily equal to a_R).[43]

If $a_L = a_R = a$, the bidders' problems are entirely symmetric. A symmetric equilibrium is easily found by setting $b = \beta(x)$ in the first order condition:

$$\beta^{SP}(x) = x + \gamma + (1 - 2a) \mid x - \gamma \mid \tag{3.30}$$

Remark: The possibility of resale thus reduces the regulator's expenses if and only if the winner of the auction gets more bargaining power than the loser ($a > \frac{1}{2}$). The analysis of Chapter 2 suggests that this result is not robust to the increase in the number of competing firms.

Note that [3.30] reduces to [3.29] when $a = \frac{1}{2}$ - as it obviously should. Note also that the equilibrium bid function does not depend on the distribution of the opponent's cost - even if bargaining power depends on the outcome of the auction.[44]

First-price auctions

I will only consider the symmetric case $a_L = a_R = a$. The first-order condition [3.24] then becomes

$$[1 - F(x)]\beta\prime(x) = f(x)[\beta(x) - x - \gamma - (1 - 2a) \mid x - \gamma \mid] \equiv g(x, \beta) \tag{3.31}$$

Although the standard existence theorem for ordinary differential equations is not applicable,[45] there is a solution that satisfies the natural boundary condition for this

[42] It can be checked that the second-order conditions for the bidders' maximization problems are satisfied at the equilibrium: the derivative of [3.24] with respect to b is $f'(b-\gamma)(x+\gamma-b)-f(b-\gamma) = -f(b-\gamma) < 0$ when $b = x + \gamma$.

[43] In the complete information case of Chapter 2, we had all firms bidding exactly the same in equilibrium. With imperfect information we could not hope for more than a symmetric equilibrium. Also not that I have not ruled out the possibility of other, non-symmetric, equilibria.

[44] The density function affects the second-order conditions, though. I have checked that they are satisfied for the case of uniform density.

[45] Note that

$$\mid g(x, \beta_1) - g(x, \beta_2) \mid = \frac{f(x)}{1 - F(x)} \mid \beta_1 - \beta_2 \mid \tag{3.32}$$

class of problems.

The boundary condition is derived as follows. The "worst" type (i.e., the firm who gets a cost of $\overline{c}$) must be indifferent between losing (as it almost surely will in any symmetric equilibrium in increasing strategies) and winning by submitting its equilibrium bid. Since the latter event only happens when the other player is also a "worst" type, the relevant condition is

$$\beta(\overline{c}) - \gamma - [\gamma + (1-a)(\overline{c} - \gamma)] = (1-a)(\overline{c} - \gamma) \tag{3.33}$$

and this gives us the boundary condition

$$\beta(\overline{c}) = 2[a\gamma + (1-a)\overline{c}] \tag{3.34}$$

Consider a firm of type $x \in [\gamma, \overline{c})$, so that $\mid x - \gamma \mid = x - \gamma$. Integrating [3.31] in $[\gamma, \overline{c})$ we have

$$\int_x^{\overline{c}} [1 - F(c)] d\beta_H(c) = \int_x^{\overline{c}} [\beta_H(c) - c - \gamma - (1-2a)(c-\gamma)] dF(c) \tag{3.35}$$

Integrating by parts and using the boundary condition yields

$$-[1 - F(x)]\beta_H(x) = -2 \int_x^{\overline{c}} [a\gamma + (1-a)c] dF(c) \tag{3.36}$$

Since we are considering the case $x \in [\gamma, \overline{c})$, we can divide both sides by $-[1 - F(x)] \neq 0$ and get

$$\beta_H(x) = 2[a\gamma + (1-a)E[c \mid c \geq x]] \tag{3.37}$$

It can be easily checked that the limit of $\beta_H(x)$ as $x \to \overline{c}$ is exactly the boundary condition [3.34], so the solution holds on the whole interval $[\gamma, \overline{c}]$.

We can then take $\beta(\gamma) = 2[a\gamma + (1-a)E[c \mid c \geq \gamma]]$ as a boundary condition for the lower segment ($x \in [\underline{c}, \gamma]$) of the equilibrium bid function. Integrating between x and γ, using integration by parts and the boundary condition at γ, one gets the

Therefore the Lipschitz condition fails unless the hazard rate is bounded on the whole closed interval $[\underline{c}, \overline{c}]$.

lower part of the equilibrium bid function

$$\beta_L(x) = 2 \quad \{Prob\{x \leq c \leq \gamma \mid c \geq x\}[aE\{c \mid x \leq c \leq \gamma\} + (1-a)\gamma] + \\ +Prob\{c \geq \gamma \mid c \geq x\}[a\gamma + (1-a)E\{c \mid c \geq x\}]\} \qquad (3.38)$$

As mentioned above, the revenue equivalence theorem is not directly applicable. The result, however, still holds:

Proposition 13 *Under the assumptions of this section, the symmetric Bayes-perfect equilibria of first-price and second-price COLR auctions lead to the same expected level of subsidies.*

Proof: Let the firms' privately known costs be x and y and, without loss of generality, assume that $x < y$.[46] Therefore, the subsidy will be equal to $S^{FP} = \beta^{FP}(x)$ in the case of a first-price auction and to $S^{SP} = \beta^{SP}(y)$ in the case of a second-price auction.[47] We will see that, conditional on any level of x, the expected subsidy is the same. Hence, *a fortiori*, the unconditional expectation of the subsidy will be the same.

Consider first the case $x > \gamma$ (and therefore $y > \gamma$). Here we have $\beta^{FP}(c) = 2[a\gamma + (1-a)E\{c \mid c > x\}]$ and $\beta^{SP}(c) = c + \gamma + (1-2a)(c-\gamma) = 2[a\gamma + (1-a)c]$. Taking expectations, we get

$$\begin{aligned} E\{S^{SP} \mid \gamma < x < y, x\} &= \frac{1}{1-F(x)} \int_x^{\bar{c}} 2[a\gamma + (1-a)y]dF(y) \\ &= 2[a\gamma + (1-a)E\{c \mid c > x\}] \\ &= \beta^{FP}(x) \\ &= E\{S^{FP} \mid \gamma < x < y, x\} \end{aligned}$$

The case $x < \gamma$ takes a bit more algebra:

$$E\{S^{SP} \mid x < \gamma, x < y, x\} =$$

[46] The case of equal costs has zero probability and cannot affect the expected subsidy. For the same reason, I will only consider strict inequalities in the following.

[47] Recall that COLR auctions are a kind of procurement auction and it is the lowest bid that wins.

$$\begin{aligned}
&= \frac{1}{1-F(x)}\int_x^\gamma 2[ay+(1-a)\gamma]dF(y)+\int_\gamma^{\bar{c}} 2[a\gamma+(1-a)y]dF(y) \\
&= 2\frac{F(\gamma)-F(x)}{1-F(x)}[aE\{c \mid x<c<\gamma\}+(1-a)\gamma]+ \\
&\quad +2\frac{1-F(\gamma)}{1-F(x)}[a\gamma+(1-a)E\{c \mid c>\gamma\}] \\
&= \beta^{FP}(x)=E\{S^{FP} \mid x<\gamma, x<y, x\}
\end{aligned}$$

Q. E. D.

3.4.4 Comparison with fixed subsidy schemes

Assume that, before the auction, the regulator's information is exactly equal to what is common knowledge for the two firms. The minimum fixed subsidy that fulfills the universal service requirements is then $s^{EPOS}=\gamma$ per market, for a total cost of $S^{EPOS}=2\gamma$.[48]

The level of subsidies generated by COLR auctions in the two cases solved in the previous section are

$$S^{SPf}(x,y)=x\vee y+\gamma$$

when bargaining power does not depend on the outcome of the auction and

$$S^{SP}(x,y;a)=x\vee y+\gamma+(1-2a)\mid x\vee y-\gamma\mid$$

when the winner of the auction gets a fraction a of the gains from trade in subcontracting, regardless of who the winner is.

As in the complete information case considered in Chapter 2, there are cases in which auctions result in lower subsidies than even the best fixed subsidy scheme. It is then clear that there are parameter values and probability distributions for which the same result holds in expectation.

[48]This assumes that demand for the service is sufficiently low, otherwise a higher subsidy would be required.

As an example, I consider the case in which the firms' types are distributed uniformly on [0,1]. In this case, $Prob(x \vee y \leq c) = c^2$ and we have

$$\begin{aligned} E[S^{SP}] &= \int_0^{\gamma} (x + \gamma + (1-2a)(\gamma - x))dx^2 + \int_{\gamma}^{1} (x + \gamma + (1-2a)(x-\gamma))dx^2 \\ &= \frac{4}{3}(1-a) + 2a\gamma + \frac{2}{3}(1-2a)\gamma^3 \end{aligned} \tag{3.39}$$

It can be shown that $E[S^{SP}] - S^{EPOS}$ is decreasing (i.e., the relative advantage of auctions with respect to uniform subsidies is increasing) in both a and γ. If $a = 0$, uniform subsidies are better; if $a = 1$, auctions are better; if $a = 0.5$, then auctions are better if and only if $\gamma > \frac{2}{3}$.

Chapter 4

Service Quality and Collusion in COLR Auctions

4.1 Introduction

The previous chapters have shown that competition for the market (or, more precisely, competition for the subsidies given to a market) can translate into significant savings, especially when regulators are poorly informed about firms' costs. There may be, however, another dimension of the Universal Service problem about which "the market" knows more than regulators: the quality of the service that firms provide to consumers.

The analysis presented so far has relied on the implicit assumption that regulators can verify whether subsidized carriers actually provide service that meets the minimum quality requirements specified in the definition of the universal service package. If subsidies are paid as lump sums and the regulator cannot (cheaply) verify the quality of service, COLRs will have no incentive to provide good quality service to any high cost consumer. Indeed, COLRs may even be willing to spend resources to degrade the quality of service provided to high-cost consumers down to the point at which those consumers will give up the subsidized service.

The problem of providing an efficient level of product quality is not particularly severe for an EPOS scheme that pays a sufficiently high subsidy. Firms will have some surplus subsidy to dissipate in their competition for consumers (with the possible exception of the costliest ones) and, roughly speaking, they will compete in price or quality according to what consumers value the most and how costly it is to produce higher quality.[1]

This suggests two potential solutions for COLR auctions as well. First, subsidies may be paid to COLRs on a per-subscriber basis. This would increase the number of consumers that COLRs will find profitable to serve and thus mitigate the perverse incentives for service quality mentioned above. However, as discussed below, the improvement in incentives may be quite modest.

Second, COLR auctions may try to achieve some competition "in the market" by appointing several COLRs per area and using per-subscriber subsidies.[2] Unfortunately, such a "solution" may be both costly and ineffective. In particular, I show below that COLR auctions for per-subscriber subsidies are more vulnerable to collusion than standard procurement auctions and COLR auctions for lump-sum subsidies.[3] Moreover, the problem is exacerbated if the auction appoints more than one COLR. *The source of the problem is precisely in the added scope for competition "in the market"*: defectors from collusive agreements in COLR auctions for per-subscriber subsidies can be punished by immediately charging low prices in the market, without having to wait till the next auction.[4]

The rest of the chapter is organized as follows. Section 2 expands on the previous

[1]Two cautionary remarks are in order here. First, if consumers also differ in their taste for quality, then inefficient levels of quality may be provided (see Tirole, 1988, section 7.5.1.) Second, the private value of quality may be lower than the social value of quality for the same reasons that led to a Universal Service policy to begin with.

[2]Appointing several COLRs per area while using lump-sum subsidies would only make things worse. First, the incentives for service quality would not improve at all. Indeed, they may worsen as each COLR tries to push high-cost consumers to get service from other COLRs. Second, as shown in Chapter 2, increasing the number of COLRs paid on a lump sum basis would increase the equilibrium level of subsidies.

[3]There is now a large literature on collusion in auctions. For the purpose of this section, Robinson (1985), Milgrom (1987), Graham and Marshall (1987), von Ungern-Sternberg (1988), and Wolfstetter (1996) provide a useful background.

[4]As will be clear later, the appointment of several COLRs does not guarantee the presence of incentives for high-quality service even if collusion is ruled out. Laffont and Tirole (2000; Section 6.4.2) discuss other potential benefits of competition in the market, but do not consider the possibility of collusion.

discussion of per-subscriber subsidies and COLRs' incentives for service quality. Section 3 builds a basic model of repeated COLR auctions and shows that the range of parameter values for which collusion is sustainable increases if subsidies are paid on a per-subscriber basis and/or if several COLRs are appointed in each serving area. It is also shown that an auction that determines endogenously (i.e., on the basis of the firms' bids) the number of COLRs can sometimes appoint several COLRs without falling prey to collusion. However, it may still be unable to generate enough incentives for high-quality service. Section 4 concludes.

4.2 Incentives for Service Quality

It is well known that a price-regulated monopolist does not have sufficient incentives to provide quality of service.[5] There are two reasons why this problem is particularly severe in the context of COLR auctions for lump sum subsidies. First, the incentives for service quality in high-cost area are simply nil. The only reason why a COLR may want to provide good service quality would be that this may increase its revenues more than its costs. But a COLR cannot increase the price of the universal service package and, by definition, COLRs lose money whenever they have to serve a high-cost consumer. Thus, to the extent that higher quality of service increases demand in high-cost areas (e.g., for second lines - if those are included in the COLR's obligation), providing higher quality of service reduces a COLR's profit even when it does not require higher costs.[6] Second, indirect monitoring of service quality is likely to be less effective. For example, surveys of customer satisfaction may be particularly unreliable. Consumers would have the incentive to complain about service quality even if the latter was as high as required by the COLR's obligation, so that the regulator would force the COLR to increase it a notch further.[7] The use of market

[5]See Armstrong *et al.*, 1994, p. 173 for a simple proof.

[6]Moreover, the increase in the demand may be at the expense of a profitable service (e.g., mobile phones).

[7]Note that the problem here is more severe than in the case of contingent valuation of public goods because the cost of higher quality would be paid mainly by consumers in low-cost areas and not by the survey respondents.

penetration targets is also likely to be less effective. In the standard analysis of price-regulated monopoly, assuming that the distribution of tastes for quality is known, regulators may infer the quality of service provided from the observed (*ex post*) prices and quantities. However, the demand for the universal service package is likely to be very inelastic. In particular, consumers may prefer to buy low quality service at regulated prices from the COLR rather than buying high quality service at a price equal to the corresponding cost from some other carrier. If so, the COLR's market penetration would have very little informational content.[8]

One possible solution to this incentive problem is, of course, to spend considerable amounts of resources in monitoring service quality directly.[9] But is it possible to devise an incentive scheme that can substitute for monitoring?

As mentioned in the introductory section, the relative effectiveness of EPOS schemes with respect to quality incentives suggests that paying subsidies on a unit (per-subscriber) basis would improve the COLR's incentives.[10] In fact, that was the motivation for introducing per-subscriber subsidies in the GTE proposal for COLR auctions.[11]

Part of the intuition for the potential effectiveness of per-subscriber subsidies in creating good incentives for service quality is that they can transform (some) high-cost consumers into consumers that are profitable for the subsidized firms. But would profitable consumers receive good service quality? Alas, the answer is: not necessarily. The problem is that the consumers that are made profitable by the switch from lump-sum to per-subscriber subsidies are made profitable only for the winning COLR.[12] The COLR would still face no competition for those (previously high-cost) consumers

[8]Perhaps more importantly, regulators are unlikely to have much information about taste distributions, so the inference would be highly imprecise anyway.

[9]In fact, regulators often do precisely that. For example, the FCC has an extensive database (ARMIS) on local exchange carriers' service quality. Several state regulators also have regular monitoring programs and impose fines on carriers that fail to comply with the required standards (e.g., Minnesota's Alternative Form of Regulation for U.S. WEST).

[10]More generally, one could devise schemes in which the relation between a COLR's subsidy payments and served customers is non-linear. The following analysis considers only the linear case, but the logic of the arguments put forward does not seem to depend on linearity.

[11]See Chapter 1 and the Appendix.

[12]See below for the case of multiple COLRs.

and would thus increase the service quality it provides them only if their demand is sufficiently elastic, e.g., if they would drop out of the network unless quality is sufficiently high.

Example 1: Assume that: (1) all firms are identical; (2) there is a unit mass of consumers indexed by $h \in [0, 1]$ such that the cost of serving consumer h with quality level $q \in [0, \infty)$ is $1 + q - h$ and every consumer is willing to pay $0.25 + q$ for service of quality q;[13] (3) the regulator wants service of quality $q \geq q_r = 0.25$ to be provided at price $p \leq \bar{p} = 0.25$.

Consider a second-price auction to appoint a single COLR. If firms bid for lump-sum subsidies, then low-cost consumers ($h \in [0.75, 1]$) are unaffected by the auction. The COLR will offer them service of quality $h - 0.75$ at price $\bar{p} = 0.25$, while all other firms may offer any price-quality combination yielding the same value. No firm will make any (extra) profit on those consumers. The COLR will be the only firm offering service to high-cost consumers ($h \in [0, 0.75]$) and it will do so at the maximum possible price ($\bar{p} = 0.25$) and minimum possible quality (zero). The COLR's net cost of serving high-cost consumers will be $\int_0^{0.75}[0.25 - (1 + 0 - h)]dh = -9/32$, which also be equal to the firms' bids and to the equilibrium subsidy.

Consider now a second-price COLR auction for per-subscriber subsidies that appoints a single COLR. Let s be the unit subsidy determined by the auction. The COLR will now be able to undercut its competitors for the low-cost consumers and get an extra profit equal to s for each of them. Consumers $h \in [0, (0.75 - s)^+]$ will still be unprofitable even for the COLR and they will receive the usual minimum quality-maximum price package. Consumers $h \in [(0.75-s)^+, 0.75]$ will have become profitable for the COLR, but only for the COLR! No other firm will be interested in serving them. Therefore, they will receive the minimum quality-maximum price package, too.[14] The COLR's profit will thus be $\int_0^{0.75}[0.25+s-(1+0-h)]dh+\int_{0.75}^{1} s dh = s-9/32$ and the equilibrium level of bids, unit subsidies and total subsidies will be 9/32, as in the case of lump-sum subsidies.

[13] I am implicitly assuming that firms set service quality separately for each consumer.

[14] The assumption that the marginal cost of quality is identical to its marginal benefit is not essential to this argument. As long as increasing quality does not increase the quantity demanded by these consumers, they will always receive the minimum quality-maximum price package.

The revenue-equivalence result in the above example is not robust: total subsidies in COLR auctions for lump-sum and per-subscriber subsidies can be dramatically different when firms are not identical, subcontracting is imperfect and service areas contain both low-cost and high-cost consumers. Here is a particularly striking example.

Example 2: Consider the model presented in Chapter 2 specialized to two firms (denoted by T for "top" and B for "bottom") and two consumer classes (denoted by H for "high" and L for "low"), but now assume that subcontracting is impossible and one of the two consumer classes (class L) is low-cost. In particular assume the following: $q_H = 1/100$, $q_L = 99/100$, $c_H^T = 900$, $c_L^T = 800$, $c_H^B = 1000$, $c_L^B = 100$, $\bar{p} = 500$. It can be easily shown that a COLR auction for lump-sum subsidies would produce the following result: T would win with a bid $b^T = 4$ against B's bid $b^T = 5$; the (total) level of subsidy would be 5 and the firms' profits would be $\pi^T = (500 - 900)(1/100) + 5 = 1$ from serving class H and $\pi^B = (500 - 100)(99/100) = 396$ from serving class L. Consider now a second-price COLR auction for per-subscriber subsidies. The minimum per-subscriber subsidy at which firm T would at least break even is 400, so let's assume that its bid will be at least that high. If the subsidy is $s \geq 400$ and firm T wins, firm B makes zero profit. But, by submitting a bid $b^B = 399$, firm B could win the auction and a unit subsidy equal to 400. It would then serve all consumers for a total profit $\pi^B = (500 + 400 - 1000)(1/100) + (500 + 400 - 100)(99/100) = 791$. The unit subsidy would be paid for all consumers at a total cost to the regulator of 400: eighty times more than the cost under lump-sum subsidies! If instead $q_H > 4/5$, then per-subscriber subsidies would be *less* costly to the regulator than lump-sum subsidies.

In the above example, the switch from lump-sum to per-subscriber subsidies is completely ineffective in bringing the quality of service received by high-cost consumers to the level required by regulators. Indeed, the only change is that high-cost consumers - who may have bought service of any quality level under the lump-sum regime - will now surely get the low-cost and (relatively) low-quality package offered by the COLR. In this example, per-subscriber subsidies ensure that (almost) everybody will get service of sub-standard quality!

The results would not change even if quality could be made negative (i.e., such that consumers would rather not buy the service at the regulated price) at sufficiently low cost.

Example 1 (cont.): For example, assume that the cost of serving consumer h with quality level $q \in (-\infty, \infty)$ is $1 - h + \max(0, q)$ and that the regulator does not impose any market penetration target. Then the COLR can evade its obligation by providing high-cost consumers with quality $q < 0$ at the regulated price. Consequently, a COLR auction for lump-sum subsidies will lead to zero subsidies - and zero quality for all high-cost consumers $h < 0.75$. But also a COLR auction for per-subscriber subsidies will lead to zero subsidies in equilibrium, so the set of consumers that are high-cost even for the COLR (and that are thus driven out of the market) is still $\{h < 0.75\}$.[15]

The above example strongly suggests that the quality effectiveness of EPOS schemes depends not only on paying subsidies on a per-subscriber basis, but also on paying them to at least a couple of firms. Could an auction for two (or more) COLR positions improve things? The answer is: maybe, but at a potentially high price.[16]

Example 1 (cont.): Let us maintain the assumptions of the previous example, but consider a third-price auction that appoints two COLRs. For simplicity, let us assume that when a set of consumers are indifferent between the packages offered by two (or more) firms, they will split evenly between those firms. It is clear that nothing important will change for the case of lump-sum subsidies: COLR's costs will be halved and so will their bids and the equilibrium level of subsidies - but those subsidies will have to be paid to two firms instead of one. Quality levels will be unchanged. Consider now the per-subscriber case. Competition between the two COLRs will wipe out all potential profits from serving low-cost consumers, i.e., all consumers h such that, for some q, $0.25 + s - (1 + q - h) > 0$ or, equivalently, all

[15] Note that this result does not depend on firms being identical.

[16] Laffont and Tirole (2000, p. 253) answer the question with an unequivocal "no", but that is because (in this context) they assume that consumers are homogeneous. Moreover, as shown in the next section, in a repeated game context it is theoretically possible to have quality improvements even when consumers are homogeneous.

consumers h such that $s - 0.75 + h > 0$. A COLR's profit will thus be equal to

$$\frac{1}{2}\int_0^{(0.75-s)^+}[0.25 + s - (1 + 0 - h)]dh \tag{4.1}$$

This is equal to $-0.25[(0.75 - s)^+]^2$. Since a COLR's profits cannot be strictly negative because of the voluntary participation (individual rationality) constraint, we must have $s \geq 0.75 = 24/32$.[17] At these subsidy levels, all consumers are profitable for the COLRs and competition among them guarantees that service quality can satisfy regulatory requirements for all consumer h such that $\bar{p} + s - (1 + q_r - h) > 0$, that is at least for all $h > 0.5$.[18] In order to guarantee that *every* consumer can be offered service of quality q_r or more, we must have $s \geq 1$.

Remark: In the above example, an EPOS scheme that pays a per-subscriber subsidy equal to $s > 0.75$ would result in exactly the same outcome as a dual-COLR auction for per-subscriber subsidies in which bidders coordinate on the equilibrium in which bids (and thus subsidies) are equal to s - a reasonable assumption if the regulator sets a reserve price equal to s.

In chapter 2 it was shown that increasing the number of COLRs increases total subsidies when subsidies are paid on a lump-sum basis. The above example notwithstanding, this is not necessarily true when subsidies are paid on a per-subscriber basis. The intuition for this difference between the two forms of subsidies is the following. First, if subcontracting is efficient, there is no gain in production efficiency by having more than one COLR with either form of subsidies. Second, in the absence of subcontracting, all high-cost consumers (i.e., those h such that $c_h^f > \bar{p}$ for all f) are going to be allocated randomly across COLRs when subsidies are lump-sum, therefore allocative efficiency cannot be expected to improve by increasing the number of COLRs even if carriers have very different cost structures. When subsidies are paid on a per-subscriber basis, instead, at least some consumers will become profitable for

[17]Recall that the subsidy was only 9/32 in the single COLR case. Because of the assumptions of homogeneous firms and Bertrand competition among COLRs, firms' profits are always zero in equilibrium. Thus non-participation, as well as any $s \in [0.75, \infty)$, is a possible equilibrium outcome.

[18]The conditional is necessary since in this model COLRs may compete in price and quality equally well.

some COLR and stay unprofitable for others. Competition among COLRs will ensure that those consumers will be efficiently "allocated" to the most suitable COLR. If the service area is not a natural monopoly, the corresponding gains in efficiency will translate (all other things being equal) into lower bids and lower subsidies. Unfortunately, as argued in the next section, the "other things" are unlikely to remain equal.

4.3 Collusion incentives and per-subscriber subsidies

This section shows that attempts to design COLR auctions that provide good *incentives for quality of service* (i.e., using per-subscriber subsidies and appointing several COLRs per service area) may be particularly vulnerable to *collusion among bidders*. The problem is that the use of per-subscriber subsidies increases the range of possible punishments for those who defect from collusive agreements. The appointment of several COLRs per area makes things worse by reducing the cost of carrying out such punishments. Competition *in the market* after the auction and competition *for the market* in the auction thus tend to be mutually incompatible. At the end of this section, however, I show that, under rather stringent conditions, making the number of appointed COLRs depend on the bids submitted in the auction may provide efficient incentives for service quality.

4.3.1 The Model

I will consider the simplest possible model of repeated COLR auctions for per-subscriber subsidies. There are N firms who have the same discount factor δ and the same technology. They can produce service of two quality levels $q \in \{0, 1\}$ at a constant marginal cost of $c + q\gamma$. There is a unit mass of identical consumers with unit demand. Consumers' willingness to pay for service of quality q is v_q such that

$\bar{p} < v_0 < v_0 + \gamma < v_1$.[19] The regulator knows $(N, \delta, \gamma, v_0, v_1)$, but does not know the firms' cost structure and she wants high-quality service to be available at a price no higher than $\bar{p}$. The timing of the models in this section is as follows:

1. The regulator chooses the number of COLRs and whether to hold a uniform-price or a discriminatory auction.[20] I will take the duration of the COLR franchise $T \geq 1$ and the reserve price $R \geq c + \gamma - \bar{p}$ as exogenously given. I will also make the following assumptions.[21] First, *the regulator runs a single auction for the whole market*, so that the gains from breaking a bidders' ring are greatest. Second, *in case of ties, the regulator will appoint the firm with the lowest code number*,[22] so that a bidders' ring cannot use the auctioneer as the randomization device that decides the winner(s) in a given auction.

2. Firms submit their (sealed) bids and the outcome of the auction is announced.

3. Immediately after the auction, and at the beginning of every period until the next auction, firms simultaneously set their prices p^f and quality levels q^f for the period. Consumers divide themselves equally among the firm(s) that offer the best deal, i.e., the highest value of $v_{q^f} - p^f$. Production takes place and payments are made.

4. After T periods, go back to stage 2.

4.3.2 Auctions for two or more COLRs

Let $M < N$ be the number of COLRs to be appointed in the area. We can then show the following:

[19]This implies that consumers would buy low quality service at the regulated price if nothing else was available, but it would be more efficient to provide high-quality service.

[20]In a uniform-price auction every winner gets a subsidy equal to the lowest rejected bid or to the highest accepted bid. In a discriminatory auction, every winner gets its bid. There are of course many other hybrid forms, but the results of this section would be unchanged.

[21]In the context of this model, it is actually optimal for the regulator to behave according to these two assumptions.

[22]Any other deterministic method (e.g., alphabetical order) would do.

Proposition 14 *If $M > 1$, then maximal bid rigging (i.e., getting a subsidy equal to the reserve price) is sustainable as a subgame-perfect equilibrium in both uniform-price and discriminatory COLR auctions for per-subscriber subsidies. This result does not depend on any other parameter of the model described in this section (in particular, it does not depend on δ, T or N).*

Proof:

Case (a): uniform $(M+1)^{th}$ price auction.[23] Consider the following symmetric strategy profile. Before any auction, M firms are chosen at random as "designated winners". They will bid $\underline{b} = c - \bar{p}$, while the others will bid R. The winners' subsidy will then be equal to R. If some "designated loser" bids $\underline{b}$ or less, the subsidy would be exactly $\underline{b}$ and everyone will bid $\underline{b}$ forever after. No immediate gain from defection would then compensate the loss of the future gains from collusion.[24]

After an auction in which no designated loser has defected from the agreement and become a COLR, and for all the T periods before the next auction, the winners will set a price equal to $\bar{p}$ and offer low quality service. The other firms will stay out of the market. If anyone sets a price lower than $\bar{p}$, then all (other) COLRs will offer high quality service at a price equal to $c + \gamma - R$[25] in the remaining periods before the next auction and everyone will bid $\underline{b}$ forever after.

It is clear that the only deviation that the colluders need to worry about is that of a designated COLR setting a price below $\bar{p}$ and/or offering high-quality service. For completeness and future reference, I characterize below the condition for this to be unprofitable, but I wish to emphasize that this condition does not affect the result claimed in the proposition: *bid rigging is an equilibrium in the auction even if collusion in the post-auction market is not sustainable!*

[23]In this case, the restriction to $M > 1$ is not important.

[24]Note that it is a subgame perfect equilibrium to bid $\underline{b}$ forever.

[25]For notational simplicity I will allow prices to be negative (e.g., firms could provide discounts on other services to their buyers of the universal service package). The analysis would be qualitatively unchanged if the non-negativity constraint were imposed.

The value of collusion for a designated winner (V^W)and a designated loser (V^L) are obtained as the solution of the following system of two equations

$$V^W = \frac{1}{M}(\bar{p} + R - c)\frac{1-\delta^T}{1-\delta} + \delta^T(\frac{M}{N}V^W + \frac{N-M}{N}V^L) \tag{4.2}$$

$$V^L = \delta^T(\frac{M}{N}V^W + \frac{N-M}{N}V^L) \tag{4.3}$$

The solution is

$$V^W = (\bar{p} + R - c)\frac{(1-\delta^T)N + \delta^T M}{MN(1-\delta)} \tag{4.4}$$

$$V^L = (\bar{p} + R - c)\frac{\delta^T}{N(1-\delta)} \tag{4.5}$$

The expected profits of a firm in the collusive equilibrium are then

$$V = \frac{M}{N}V^W + \frac{N-M}{N}V^L = (\bar{p} + R - c)\frac{1}{N(1-\delta)} \tag{4.6}$$

A COLR's deviation from collusion in the market (i.e., setting a price of $\bar{p} - \varepsilon$ ($\varepsilon \in (0, \gamma)$) and getting the whole market for the period) at the beginning of the t^{th} period after an auction will be unprofitable if

$$(\bar{p} - \varepsilon + R - c) < (\bar{p} + R - c)\frac{1}{M}\frac{(1-\delta^{T-t})}{(1-\delta)} + \delta^{T-t}V \tag{4.7}$$

If we take ε to be arbitrarily small, "hence" zero, and substitute the value for V, the gains from deviation become

$$(\bar{p} + R - c)\Big(1 - \frac{(1-\delta^{T-t}N + \delta^{T-t}M)}{MN(1-\delta)}\Big) \tag{4.8}$$

These gains are maximal in the period just before a new auction - the defecting COLR can get its booty only once, so it had better get the "normal" COLR profits in the first T-2 periods. Collusion in the market will be sustainable if

$$(\bar{p} + R - c)(1 - \frac{(1 - \delta N + \delta M)}{MN(1 - \delta)}) < 0 \tag{4.9}$$

or

$$M < \frac{N(1 - \delta)}{N(1 - \delta) - \delta} \tag{4.10}$$

This shows that increasing the number of COLRs per area can indeed provide sufficient incentives for competition “in the market”. Note that this condition does not depend on the reserve price, i.e., on the level of collusion. Therefore a bidding ring cannot increase its cohesiveness by being less greedy and getting a subsidy lower than R.

Case (b): uniform M^{th} price auction, i.e., subsidy equal to the worst accepted bid. The analysis is similar to the case of discriminatory auctions below and is thus omitted.

Case(c): discriminatory ”get-your-bid” auction. The collusive outcome in the auction is now achieved by having the designated winners bid R and the designated loser not participate at all.[26] A designated loser who defects from the agreement and bids $R - \varepsilon$ would immediately be punished by the other COLR(s) who would all switch to the non-collusive equilibrium and offer high quality service at a price equal to $c + \gamma - R$ thus depriving the defector of any profit.[27] The rest of the analysis is analogous to the one of case (a).

Q. E. D.

In the case of discriminatory auctions, the above proof uses the fact that $M > 1$ (and that competition is Bertrand-like) since it relies on the fact that the punishment of defectors does not entail negative payoffs for the punishers. The continuation strategies after the punishment phase, in fact, give zero payoff to everyone, so losses would not be recovered.

[26] Alternatively, the designated winners could bid $R - \varepsilon$ and the designated losers would bid R

[27] Recall that we are assuming Bertrand competition. Note that this kind of punishment strategy would not be possible in a standard procurement auction, nor in a COLR auction for lump-sum subsidies.

This may suggest that the auction vulnerability to bid rigging may not be as bad as it looks. Although collusion in the auction is a Nash equilibrium, it is not necessarily a strong equilibrium, i.e., it can be vulnerable to defection from a coalition of players. In fact, if $N \geq 2M$, it may be profitable for M designated losers to jointly defect from the collusive agreement and clinch all the COLR positions. The defeated would-be COLRs would then lose the subsidy and would no longer be able to wipe out the defectors' profits without incurring in immediate losses themselves.[28]

This does not change the fact, however, that COLR auctions for per-subscriber subsidies are more vulnerable to collusion than COLR auctions for lump-sum subsidies (and standard procurement auctions). The following subsection shows that this is true even if $M = 1$.

4.3.3 Single COLR Auctions for per-subscriber subsidies

We have already shown that second-price single-COLR auction admit collusive equilibria. Now consider a first-price COLR auction that appoints a single COLR (i.e., $M = 1$).

The payoffs from sticking to the collusive agreement are now given by

$$V^W = (\bar{p} + b_c - c)\frac{N(1-\delta^T)+\delta^T}{N(1-\delta)} \tag{4.11}$$

$$V^L = (\bar{p} + b_c - c)\frac{\delta^T}{N(1-\delta)} \tag{4.12}$$

$$V = (\bar{p} + b_c - c)\frac{1}{N(1-\delta)} \tag{4.13}$$

where $b_c \leq R$ is the designated winner's bid (of course, $b_c \geq c - \bar{p}$).

Consider the deviation from a designated loser bidding $b_d < b_c$ and becoming the sole COLR. It will be clear that a defector would bid right below b_c so we will simplify matters by assuming that the defector can become a sole COLR by bidding exactly b_c. In a standard procurement auction or in a COLR auction for lump-sum subsidies,

[28] If firms' costs differ, it would also be impossible to wipe out the profits of a single defector when that defector is the lowest-cost firm.

the worst punishment that can be inflicted to such defector is to bid $\underline{b}$ at any future auction. This punishment is still possible here, of course, and it will suffice if

$$(\bar{p} + b_c - c)\frac{1-\delta^T}{1-\delta} \leq V^L \tag{4.14}$$

which is equivalent to

$$N \leq \frac{\delta^T}{1-\delta^T} \tag{4.15}$$

In this case, as expected, collusion is more likely if the number of firms is small, the COLR franchise is short, and the firms patient. Note also that, with the punishment strategy outlined above, if collusion is sustainable at all, then it is sustainable in the maximal degree, i.e., with $b_c = R$.

The following shows that, in COLR auctions for per-subscriber subsidies, some degree of bid rigging can be sustainable even if condition (4.15) is violated.

Consider the following punishment strategy.[29] If a designated loser actually wins, then the other N-1 firms will all offer high-quality service at price $\hat{p} \equiv (c + \gamma - b_c)$ for all the periods before the next auction. They will then revert to the collusive strategy.[30] If anyone fails to punish a defector, then the punishment phase will end immediately and everyone will bid $\underline{b}$ forever after.

This is clearly enough to dissuade any would-be defector: it would get no immediate payoff and possibly lose some future gains from cooperation. It remains to check whether punishment is individually rational.

The payoff of a "punisher" is now

$$\frac{(\hat{p} - c - \gamma)}{N-1}\frac{(1-\delta^T)}{(1-\delta)} + \delta^T\frac{(\bar{p} - b_c - c)}{N}\frac{1}{(1-\delta)} \tag{4.16}$$

[29]This punishment is not necessarily the most effective, but it suffices for the purposes of this section.

[30]This makes defection irrelevant with respect to the defector's payoff. If one wants punishment to be strict, then there may be competitive bidding for one or more auctions before reverting to the collusive equilibrium. It would also be possible to revert to a collusive equilibrium in which the defector has a lower probability of winning than the other firms.

and it is positive whenever

$$\frac{N}{N-1} \leq \frac{\delta^T}{(1-\delta^T)} \frac{(\bar{p}+b_c-c)}{b_c} \tag{4.17}$$

Remark: It is interesting to note that *collusion is more likely to be sustainable if it is done at a higher level* (i.e., with $b_c = R$). The intuition is clear: the more profitable collusion is, the easier it is to get back the cost of punishing defectors. Similarly, and perhaps more surprisingly, *the bidding ring is sometimes more likely to work if there are more firms*, because this allows to share the cost of punishments more evenly.

The above condition can then be rewritten as

$$N \leq \frac{\delta^T}{(1-\delta^T)}(1-\frac{c-\bar{p}}{R})(N-1) \tag{4.18}$$

Condition (4.18) will be more easily satisfied than (4.15) if and only if

$$\frac{N-2}{N-1} > \frac{c-\bar{p}}{R} \tag{4.19}$$

which is satisfied if, for example, $\bar{p} = 20, c = 40, R > 30, N > 4$. Since the punishment strategy that generates (4.15) is always available, we have shown

Proposition 15 *Bid rigging is more likely to be sustainable if subsidies are paid on a per-subscriber basis.*

4.3.4 Endogenous number of COLRs

The model presented above is an extremely simple idealization, but the result seems transferable to a much broader (and realistic) range of settings: if subsidies are paid on a per-subscriber basis, collusion in COLR auctions becomes easier. This effect is strengthened by the appointment of more than one COLR per service area because the punishment of defectors is thus made easier for the non-defecting COLRs.

The regulator, however, has a few options that may mitigate this problem. In theory, the regulator could impose a price floor equal to $\bar{p}$. This would limit the immediate punishment of a defector to γ. In practice, this may be quite problematic. If there are low-cost consumers in the area, the regulator risks becoming not only the protector, but the necessary cause of collusion in the market. Moreover, it is not clear whether the Telecommunications Act gives the regulator the power to impose price floors. A (certainly legal) alternative would be to adjust the reserve price downward whenever the price charged to consumers drops below $\bar{p}$ and thus limit the possibility of recovering the losses incurred in the punishment of defectors.[31]

The rest of this section shows that making the number of COLRs a suitable endogenous function of the bids received may be another way to alleviate the problem of collusion.

The idea of making the number of COLRs dependent on the firms' bids already appears in the GTE proposal, Milgrom (1996) and, in different contexts, in the literature on regulation with endogenous market structure.[32] The rationale is to trade off the value of added competition "in the market" among two (or more) firms against the cost of accepting the second-best (or worse) bid.

As shown below, this design may even eliminate that trade-off and allow the regulator to get the best of both worlds: appoint several COLRs who will compete "in the market" while guaranteeing competition "for the market" (hence lower subsidies) under the same conditions needed for the case of single-COLR auctions.[33]

Let Δ be maximal difference between the two best bids that makes both acceptable.[34] Without immediate punishment, a designated loser would gain from defecting

[31] Of course, this would also increase the likelihood of collusion in the market.

[32] See Chapter 1. In particular, Dana and Spier (1994) have shown in a one-stage, two-firm model of auction for licenses that a "modified second-price auction" may be constrained optimal. Their auction rule awards two production licenses if the two firms' bids are both above a threshold that depends on the opponent's bid. Otherwise only the highest bidder would be awarded a production license.

[33] Note, however, that there may be no trade-off to begin with. For example, even if there are no "niche" carriers, or if there are significant costs to enter the auction, a larger number of winners may increase participation and lower the equilibrium level of subsidy (Seshadri *et al.*, 1991).

[34] I am assuming that Δ does not depend on the bids. The GTE proposal, instead, called for Δ to be defined as a fraction of the lowest bid.

and becoming a sole COLR if for some $t \leq T$

$$(\bar{p} + b_c - \Delta - c)\frac{1-\delta^t}{1-\delta} > V^L \Leftrightarrow$$
$$\Leftrightarrow \Delta < (\bar{p} + b_c - c)\frac{(N(1-\delta^t) - \delta^T)}{N(1-\delta^t)} \tag{4.20}$$

Remark: Note that a choice of Δ that simply reflects the trade-off between competition and subsidy may be too high to make defection interesting.

The usual calculations show that immediate punishing of this defection would not occur if

$$(\bar{p} + R - c) < \frac{N(1-\delta^t)}{(N-1)\delta^t}(R - \Delta) \tag{4.21}$$

Therefore the regulator could be able to appoint several COLRs without risk of collusion if

$$\frac{\Delta N(1-\delta^t)}{(N(1-\delta^t) - \delta^T)} < (\bar{p} + R - c) < \frac{N(1-\delta^t)}{(N-1)\delta^t}(R - \Delta) \tag{4.22}$$

There are two reasons why one should not look at this result with too much optimism. The first reason is that the regulator is unlikely to have enough information to set a value of Δ that is compatible with (4.22), even if such a value existed. The second is that (4.22) may be satisfied only for values of Δ so low that the appointment of more than one COLR would be useless. To see why this may be the case, assume that (4.22) is satisfied and there is no collusion in the auction at any level of bidding higher than $c - \bar{p} + \Delta$. But then, if $\Delta < \gamma$, no firm will have any incentive to provide high-quality service. Competition "for the market" could completely cannibalize competition "in the market."

4.4 Conclusion

This chapter has highlighted a serious danger in the use of auctions for Universal Service subsidies. The danger arises from the temptation of asking too much of auctions. Auctions can muster competition "for the market" effectively and reduce the cost of subsidization, but attempts to achieve strong competition also "in the market" may backfire and result in the loss of competition altogether. A clever auction design may sometimes reduce these dangers, but not always eliminate them.

However, one should not exaggerate the effect of potential collusion on the choice of the subsidization mechanism. If the reserve price is set at the same level that would be used for the subsidy in an EPOS scheme, then auctions will generally be (weakly) cheaper even in the case of collusion and the results of chapter 2 show that the imposition of such reserve prices will seldom cause (severe) problems. The lesson to be learned from this chapter is that, even if COLR auctions are used, the value of knowledge about firms' costs (and thus about optimal reserve prices) and about the quality of the service provided by subsidized firms does not vanish. Regulators still have an important role to play.

Chapter 5

Conclusions

5.1 Comparing COLR auctions and EPOS schemes: A summary

This dissertation has looked at COLR auctions and EPOS schemes from a variety of angles. It is now time to bring together the various threads and to highlight some of those that remain to be weaved.

First, let us summarize informally the results obtained in the previous chapters:[1]

- COLR auctions (even without reserve prices) are more likely to require lower subsidies than EPOS schemes when:
  - Consumer are more heterogeneous (in terms of the cost of serving them);
  - Firms have more similar cost structures;
  - The service area is closer to a natural monopoly;

[1]Although not mentioned below, some of the formal results obtained in this dissertation have independent value, beyond the comparison of COLR auctions and EPOS schemes. In particular, the models in chapter 2 and 3 can be seen as a fairly general analysis of procurement auctions when the object of procurement is a composite object and subcontracting is allowed. Section 3.2 puts the procurement auction in a Markov-game context (admittedly, a rather crude one) that takes into account the need for long term productive assets.

  - COLRs can appropriate a larger share of the gains from trade in subcontracting.[2]

- If an EPOS equal to r satisfies the Universal Service goal and the least profitable consumer is also the costliest one for the firm that serves it, then a COLR auction with reserve price r also satisfies the Universal Service goal (and with lower subsidies if the reserve price is not binding).[3] However,

- COLR auctions with excessively low reserve prices may leave the whole service area unserved, while the performance of EPOS schemes degrades more gracefully with the underestimation of production costs. On the other hand, COLR auctions suffer less than EPOS schemes from overestimation of production costs.[4]

- Appointing more than one COLR does not reduce the equilibrium level of (lump-sum) subsidies in a COLR auction even if the firms' cost structures are very heterogeneous.[5]

- EPOS schemes are more likely to provide efficient incentives for service quality. COLR auctions that pay per-subscriber subsidies and that can appoint more than one COLR per area may also provide good incentives for service quality. However, they are more vulnerable to collusion among bidders.[6]

The basic versions of COLR auctions and EPOS schemes differ on two major dimensions: the need for *a priori* information about firms' costs and the degree of centralization in the choice of subsidized firms. These differences in structure can be used to understand the origin of the differences in performance with respect to the price and service quality received by subsidized consumers and in the amount of

[2]See chapter 2 for the basic model and chapter 3 for some generalizations. In particular, the imposition of unbundling requirements on incumbents does not affect the qualitative results in the comparison between COLR auctions and EPOS schemes (see section 3.2). An interesting (curious?) result derived there is that unbundling obligations may actually benefit the incumbent.

[3]See section 2.3.

[4]See sections 2.3 and 2.4.

[5]See section 2.5.

[6]See chapter 4.

resources to be spent by regulators (hence by taxpayers) in *ex ante* cost estimation, *ex post* monitoring of compliance and, of course, subsidies.

5.1.1 Information about costs: revelation from bids vs. ex ante estimation

COLR auctions, like all auctions, rely on competition among bidders to determine the value (or, in this case, the cost) of the object being auctioned. Through their bids, firms reveal their cost of assuming the COLR obligation. If competitive forces are strong enough, the lowest bid and the level of subsidies will be close to the actual production costs (minus the regulated price to be paid by consumers) of the most efficient firm, which we can take as the "true" cost of the COLR obligation.

EPOS schemes, instead, fix subsidy levels only on the basis of *a priori* information about firms' costs. The level of competitiveness in an area may affect the required level of subsidy,[7] but not even the most extreme form of competition (e.g., Bertrand competition among identical firms without binding capacity constraints) will help a regulator that overestimates that level. Therefore EPOS schemes require sufficiently precise (hence sufficiently costly) estimates of firms production costs to determine the level of subsidies.[8]

Information about firms' costs would also be valuable in the case of COLR auctions, as it could be used to set reserve prices (i.e., maximum bids).[9] However, the value of that information is likely to be lower with COLR auctions than with EPOS schemes because reserve prices may reduce the equilibrium level of subsidies from a COLR auction only when there is little competition among firms, i.e., when firms collude (see section 4.3) or when one firm has a large cost advantage over all others.[10]

[7] But only firms' competition for the costliest consumers matters in this regard (see section 2.2.2).

[8] As discussed in chapter 1, the existing cost-proxy models have proved very expensive to develop and have often produced unreliable results.

[9] It is important to note that the information required to set appropriate EPOS levels and appropriate reserve prices in COLR auctions is different: "maximal" costs for EPOS levels and "average" costs for reserve prices. It is not clear which kind of information is more easily obtained.

[10] To be more precise, in the case of efficient subcontracting, when there is a sufficient number of consumers for which one firm (not necessarily the same for all such consumers) has a large cost advantage over all others. See section 2.2.4 for details.

If competition is strong enough (and the reserve price is high enough to cover some firms' costs), the reserve price will not bind, nor matter. Therefore, if regulators believe that strong competition is sufficiently likely, COLR auctions can rely on less precise (hence less expensive) cost estimates and set relatively high reserve prices (if any).[11]

5.1.2 Centralized procurement vs. decentralized market subsidies

Possibly the most fundamental difference between COLR auctions and EPOS schemes is that the former appoint at least one COLR and the latter do not.[12] The presence of a compliant COLR guarantees that the Universal Service goal will be satisfied – generally by the COLR, either directly or as a reseller, since the COLR is the only subsidy recipient. EPOS schemes, instead, only fix the level of subsidies and leaves the subsidies available to all firms that offer the Universal Service package. This difference has three major consequences.

First, appointing a COLR and making it the sole subsidy recipient leads to subsidies equal to an average of the net cost of serving consumers in the area.[13] EPOS schemes, instead, must pay a subsidy that is high enough to make even the costliest consumers attractive to some firms – and pay that for *every* consumer. This is the main reason why COLR auctions require lower subsidies than EPOS schemes in a wide range of circumstances.

The second consequence, closely related to the previous one, has not been analyzed formally in this dissertation, but is easily described. The concentration of subsidies

[11] It should also be recalled (from section 2.3) that COLR auctions may be particularly vulnerable to excessively low reserve prices. To the extent that this reduces the value of imposing reserve prices at all, it also further reduces the value of cost information for COLR auctions. Of course, if little competition is expected and reserve prices are to be imposed, then the value of information will be high for COLR auctions, too. The optimal information acquisition and reserve price policies will depend in general on regulators' valuation of the cost of subsidies (i.e., on the social cost of funding for Universal Service) and of possible failures to satisfy (fully or partially) the Universal Service goal. See section 2.4 for a brief discussion.

[12] Chapter 2 also briefly discusses the case of "constrained" EPOS schemes in which acceptance of the COLR obligation is a pre-condition for receiving subsidies.

[13] See chapter 2 and 3 for details on the precise kind of average.

on COLRs suggests that COLR auctions cannot accommodate changes in the set of efficient firms (e.g., due to entry of technological innovators) after the auction. This charge, if true, would be quite damning for COLR auctions because the increased speed of technological progress in the telecommunications sector was possibly the main reasons for the modern push towards deregulation and the competitive provision of Universal Service. The charge, however, is less serious than it seems. First, subcontracting may be used to achieve production efficiency by delegating production to the most efficient firms at any time. Second, unlike the case with EPOS schemes, the expected gains from cost-saving technological progress could be transferred (at least partially) to regulators by competitive pressure in the bidding process.[14] Finally, it should be recalled that the duration of the COLR obligation put up for auction (or, equivalently, the frequency of auctions in any given area) is a regulatory choice variable. A shorter duration can provide enough flexibility in accommodating new entrants, though this advantage should be traded-off against an increase in the sustainability of collusion (see chapter 4) and, perhaps, a reduction in the protection of COLRs long-term investments in the area.[15]

Finally, EPOS schemes tend to make most consumers profitable for several firms,[16] As a consequence, competition "in the market" is likely to provide sufficient incentives for subsidized firms to offer an efficient price-quality mix to most consumers.[17] A sole COLR, instead, will not have any incentive to provide service quality to high-cost consumers. Indeed, if paid on a lump sum basis, may have an incentive to degrade quality as much as possible. If the regulator cannot costlessly observe whether a COLR provides service that meets the requirements of the Universal Service goal, then it must spend resources to acquire that information – or try a different auction design. As shown in chapter 4, appointing more than one COLR per area (perhaps

[14]EPOS levels could also be periodically adjusted for technological progress, but firms are arguably better informed than regulators on this dimension, too.

[15]EPOS schemes do not offer any such protection. Whether it is needed depends largely on the same kind of considerations that determine the choice between regulation and competition (see Goldberg, 1976) and is thus beyond the scope of this dissertation.

[16]If they do not, they are almost surely dominated by COLR auctions – especially if consumers have a high value for the Universal Service package.

[17]It also leads to prices below the regulated maximum for those consumers. As shown in chapter 2, subsidized consumers are always better off under an EPOS scheme than under a COLR auction.

contingently on the best bids being sufficiently similar) and paying them on a per-subscriber basis can sometimes provide sufficient incentives for service quality by inducing COLRs to compete "in the market" with each other (after having competed "for the market" with the other bidders in the auction). Unfortunately, it can also increase the sustainability of collusion among bidders for two reasons. First, because per-subscriber subsidies increase the range of punishments to which "defectors" from collusive agreements can be subjected to (precisely by competing with them "in the market"). Second, because the presence of several COLRs reduces the cost of carrying out the punishment: for any single "defector," there will always be at least another COLR that can compete away the subsidies. The increased likelihood of collusion implies an increased expected level of subsidies.[18]

5.2 Implementation of COLR auctions: open problems

This dissertation does not provide an exhaustive analysis of COLR auctions. In particular, the fine tuning of COLR auction design has received some consideration here only to the extent that it could inform the choice between auctions and fixed subsidies. But a regulator that has decided to use COLR auctions has still a lot of choices to make. The rest of this section highlights the major ones and some of the corresponding opportunities for further research.

5.2.1 Service area boundaries and reserve prices

In principle, regulators could conduct separate COLR auctions for each single consumer. Such a choice, however, would be not only impractical, but probably also suboptimal – at least if subcontracting is not perfectly efficient. First, as shown by the literature on bundling (e.g., see Chakraborty, 1999), regulators could probably

[18]The level of subsidies could be limited by appropriate reserve prices, as discussed in the previous section. Ex ante information about costs and ex post information about quality are thus substitute goods.

reduce the level of subsidies by bundling consumers together into service areas even if there were no cost synergies across consumers. Second, synergies across consumers are likely, and this provides a further motive for bundling in the absence of subcontracting. On the other hand, synergies are unlikely to be big enough to create natural monopoly conditions. The problem is, literally, to draw the appropriate boundaries.[19] This is made more complicated by the fact that carriers employing different technologies (e.g., traditional wireline, fixed wireless, cellular, satellite) may different synergy structures and thus different preferred aggregations. A further consideration is that regulators may have reasonably accurate estimates of the average cost of providing service in a very large area (e.g., the incumbents' service areas), but lack good information at a more disaggregated level. The GTE proposal (see Appendix) suggested to divide the incumbent carriers' service areas into much smaller service areas, fix the (weighted) sum of the reserve prices in all areas and let the incumbent carriers reallocate that sum across service areas. Opponents of the GTE proposals claimed this would give incumbents an opportunity to stash away monopolistic profits in areas where entry is unlikely. On the other hand, the likelihood of entry in an area will depend on the amount of subsidies expected in that area. A formal analysis of the conditions (if any) under which the "stashing away" strategy would be feasible remains to be done. It also remains to be studies whether the availability of such strategy would be a socially efficient way to ensure incumbents are compensated for potential stranded assets, especially non-transferable ones.[20]

5.2.2 Timing

The problem of determining the duration of the franchise is not specific to COLR auctions. The choice between short-term and long-term contracts generally involves a trade-off between maintaining flexibility and providing good incentives for long-term

[19]Small areas may also make entry into the market easier, regardless of heterogeneity problems. A new entrant would need to make investments on a smaller scale and would be able to accumulate experience (and money) in serving the area before expanding its operations. This is not only a direct advantage (also from a political point of view), but can also contribute to lower the level of subsidies because it can increase the competitiveness of the auction.

[20]See section 3.2.

illiquid investments. The trade-off may be particularly uncertain in the COLR context. Technological progress is expected to be quite intense and unpredictable in the telecommunications market and this seems a point in favor of short-term contracts. On the other hand, the currently standard technology for providing telephone services still involves burying cables in the ground, largely a sunk investment. Especially because of the uncertainty about future technologies, firms may demand a high premium to make those investments unless they are given a long-term contract.[21] Perhaps the most important factor in favor of long COLR franchises is the threat of collusion. This is a potentially serious threat since it is quite likely that just a few firms will compete to become COLRs in any single area. Collusive equilibria may be made less likely by decreasing the frequency of the auctions (i.e., by increasing the duration of the COLR franchise) and by holding all auctions at the same time.[22] The GTE proposal deals with this flexibility-incentives trade-off by giving longer franchises to new COLRs as an extra incentive to enter the market. Although this may bias the outcome of the auction, the advantage thus given to entrants could lower the expected level of subsidy if entrants are likely to be at a cost disadvantage with respect to the incumbent.[23] A more complete dynamic analysis of these issues remains to be done.

5.2.3 Qualification requirements, transition and penalties

Qualification requirements tend to reduce the number of potential bidders and thus increase the competitiveness of the auction. Yet, qualification requirements are commonly imposed in procurement auctions. The obvious rationale for qualification requirements is to ensure a smooth and rapid contract execution after the auction is concluded. However, this trade-off has not been much studied in the literature.[24] For example, it seems possible that the use of subcontracting agreements *before* the auction could represent a way to enforce collusion. If that is the case, forcing bidders to show that they either have own facilities or that they have already acquired the

[21] See Goldberg (1976).
[22] See chapter 4.
[23] See Rothkopf *et al.* (1996).
[24] See Bajari and Tadelis (1999) for an exception).

option of using other firms' facilities would be precisely the wrong thing to do.

If this kind of qualification requirements are relaxed, however, regulators should probably take care of allowing fairly long transition periods before new COLRs assume their obligations and imposing heavy fines for non-compliance.[25] This should strengthen the bargaining power of new entrants, should they become COLRs, and thus lead to lower subsidies.[26]

The analysis of pre-existing contracts on auction outcomes and, more generally, the analysis of qualification requirements and compliance penalties in procurement auction is another interesting topic for future research.

5.2.4 Bidding format

The choice of bidding format is closely related to the choice of service areas. If the territory is divided into smaller service areas, bidders are more likely to have a variety of patterns of significant synergies across service areas. This suggests the use of combinatorial auction designs. Generalized Vickrey auctions are known to be revenue maximizing (in the COLR context, cost minimizing) among efficient mechanisms (see Krishna and Perry, 2000), but may be computationally unfeasible (see Rothkopf et al., 2000). The design of feasible combinatorial auctions is a very active research field, but feasibility is not the only concern. There may be other (inefficient) mechanisms that lead to lower subsidies (e.g., see Krishna and Rosenthal, 1996). It would be useful to determine some conditions on carriers' cost structures under which simple simultaneous, sequential or combinatorial auctions minimize total subsidies, taking into account subcontracting possibilities.

[25] Financial guarantees for the payment of such fines could be the right qualification requirement.

[26] See chapter 2. Strengthening the bargaining power of COLRs would be quite easy if firms knew each others' costs. It would be enough to oblige COLRs to make only one take-it-or-leave-it offer to each of other firms. In practice, however, firms are not completely informed about each other's costs and this restriction would reduce the efficiency of bargaining.

5.2.5 Allocation rule and payment format

There are two potential reasons for appointing more than one COLR per service area. The first and most direct reason is that it may be technologically efficient to do so. Although diseconomies of scale are very unlikely (indeed, the likely relevance of fixed costs is an argument in favor of single COLRs), it may still be efficient to appoint several COLRs if different consumers are served at lowest cost by different firms and subcontracting is inefficient or if firms' products are differentiated. The second reason is that it may be the cheapest way to guarantee that COLRs do not shirk their responsibilities and provide sufficient service quality.[27] If fixed costs are important, however, the appointment of several COLRs may do more damage than just increasing total production costs. It also makes bidders' valuations of the COLR franchise depend on the number of subsidized competitors with whom they will have to share the market. This requires more sophisticated bidding and may result in inefficient assignation of COLR franchises.

The choice of per-subscriber subsidies (practically inevitable if multiple COLRs are appointed) may also distort competition in areas that have both high-cost and low-cost ones. In particular, it may introduce a form of externalities in the auction that has been almost completely ignored in the literature: each bidder may have an interest in (other) COLRs receiving lower subsidies, as this would make them weaker competitors in the profitable market segments.[28]

5.3 Conclusion

Should regulators choose COLR auctions to allocate "competitively neutral" Universal Service subsidies? As usual, the answer is: it depends. The goal of this dissertation has been to show some of the conditions on which this choice depends.

[27] See chapter 4

[28] Recall that, unlike the designer of more standard procurement auctions, the COLR auctioneer does not have the legal authority to forbid entry in the market. The market structure can only be controlled via the auction rules determining the number of COLRs and their compensation. Even if the regulator appoints only one COLR per area, COLRs may still have to share the market with other carriers. See section 4.2 and the references cited there.

If service quality is easily observable, information about firms' costs is hard to obtain (but it is expected that consumers differ in their cost of service and that firms agree on which ones are more costly) and subcontracting is reasonably efficient, then simple COLR auctions are likely to be a good competitively neutral mechanism for Universal service provision. Suitable changes to the basic design can make COLR auctions a good choice also when some of those conditions are not satisfied – though providing incentives for hard-to-monitor service quality does seem a problem. Clearly, not all questions have been answered and the practical implementation of COLR auctions still requires further study. The results obtained in this dissertation suggest that COLR auctions deserve it.

Appendix A

GTE's proposal for COLR auction

The following is an overview of the proposal for COLR auctions presented by GTE at a workshop organized by the California Public Utility Commission (CPUC) on May 8 and 9, 1997. A more complete presentation is in Weller (1999).[1]

First, the proposal identified service areas with Census Block Groups (CBGs).[2] This choice, like the choice of a sealed-bid non-combinatorial format, was motivated in part by the results of cost-proxy simulations that failed to show significant economies of scope across CBG for a network with fixed locations of wire-centers.[3] Another important consideration was the arbitrariness of larger aggregations. For example, identifying service areas with the areas covered by the wire centers invites the question of which carrier's wire-centers should be considered. Moreover, wireless carriers may have a completely different structure of synergies across locations.

Second, subsidies would be paid on a per-subscriber basis in order to give COLRs

[1]The actual proposal and later comments of GTE and other participants in the workshop are part of CPUC's record in Universal Service Proceeding R. 95-01-020/021.

[2]CBGs were at the time the smallest geographical unit for which the existing cost-proxy models were able to provide cost-estimates. The FCC's most recent Hybrid Cost Proxy Model, however, is not constrained to operate on CBG-level data.

[3]These results, however, must be taken with the customary grain of salt. The cost-proxy models available at the time may have been biased against the finding of synergies. Moreover, even current cost-proxy models are based on wire-line technology and thus give no indication about the potential for synergies in the cost structure of some of the most likely new entrants in the local phone market. Ausubel *et al.* (1997) find small geographical synergies from their analysis of PCS spectrum auctions, but they are concerned with much larger areas than CBGs.

a better incentive to provide high-cost consumers with good service quality.[4]

Third, Incumbent Local Exchange Carriers (ILECs) would be allowed *una tantum* to partially redistribute the existing level of Universal Service support (determined by a cost-proxy model) across the CBGs they currently serve. The new "rebalanced" rates would be used as interim support levels until a CBG were put up for auction and would form the basis for the auction's reserve prices. This "rebalancing" phase, intended to correct possible errors in the existing support levels, was criticized by some as giving ILECs an opportunity to stash away subsidies in CBGs where they felt less threatened by competition. It must be noted, however, that concentrating subsidies in some CBGs may simply attract competitors there. If competitors fail to materialize in a given CBG, it could be inferred that the forward-looking cost of providing service is higher than the amount of subsidies stashed away there and the rebalancing phase may be justified.

Fourth, and even more controversial, GTE suggested that an ILEC who loses a COLR auction should be relieved of the obligation to provide Unbundled Network Elements at regulated prices.[5] The evaluation of this provision depends on a general analysis (legal, as well as economic) of interconnection regulation beyond the domain of the Universal Service policy, and thus beyond the scope of this dissertation.

Fifth, every six months there would be a "nomination phase". During this phase, existing COLRs would be able to resign their position in any of "their" CBGs. If a COLR resigned, other qualified firms that were not COLRs in the same CBG could apply to take its place at the existing support level. If more than one firm offered to do so, an auction would be conducted between them. If no firm came forward, than the CBG would be put up for auction and the reserve price would be set at a higher level than the existing subsidy. A CBG could also be put up for auction if some firm (possibly one of its COLRs) or the regulator nominated it. This would not be permitted, however, if less than three years had passed since the last change in the set of COLRs for that CBG.

Finally, the auction would be run in a sealed-bid format. The sealed-bid format

[4]See Chapter 4 for a formal analysis of this issue.

[5]The obligation is described in Section 251 of the Act.

was preferred to a simultaneous open (descending) format, mainly to reduce the opportunities for collusion among bidders. The proposed allocation rule was rather complex. All bids within a pre-specified range of the lowest bid would be accepted. If no other bid was within that range, then the second lowest bid would be accepted if it was within a broader range. The winning bidders would be appointed as COLRs at a support level equal to the highest accepted bid.[6] This allocation rule would not be adequate in the case of large fixed per area costs. For this reason, GTE's proposal also included an alternative bidding format. Firms would submit two-dimensional bids that approximately represent demand functions for the number of COLRs. The first bid component would specify the subsidy requested for being the sole COLR, while the second component would be for the appointment as one of several COLRs. The auctioneer would then choose the combination of bids that generates the highest value, taking into account the assumed welfare advantage of having several winners.

[6]Special rules were suggested for the case of bids for zero subsidies and for bid withdrawals.

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